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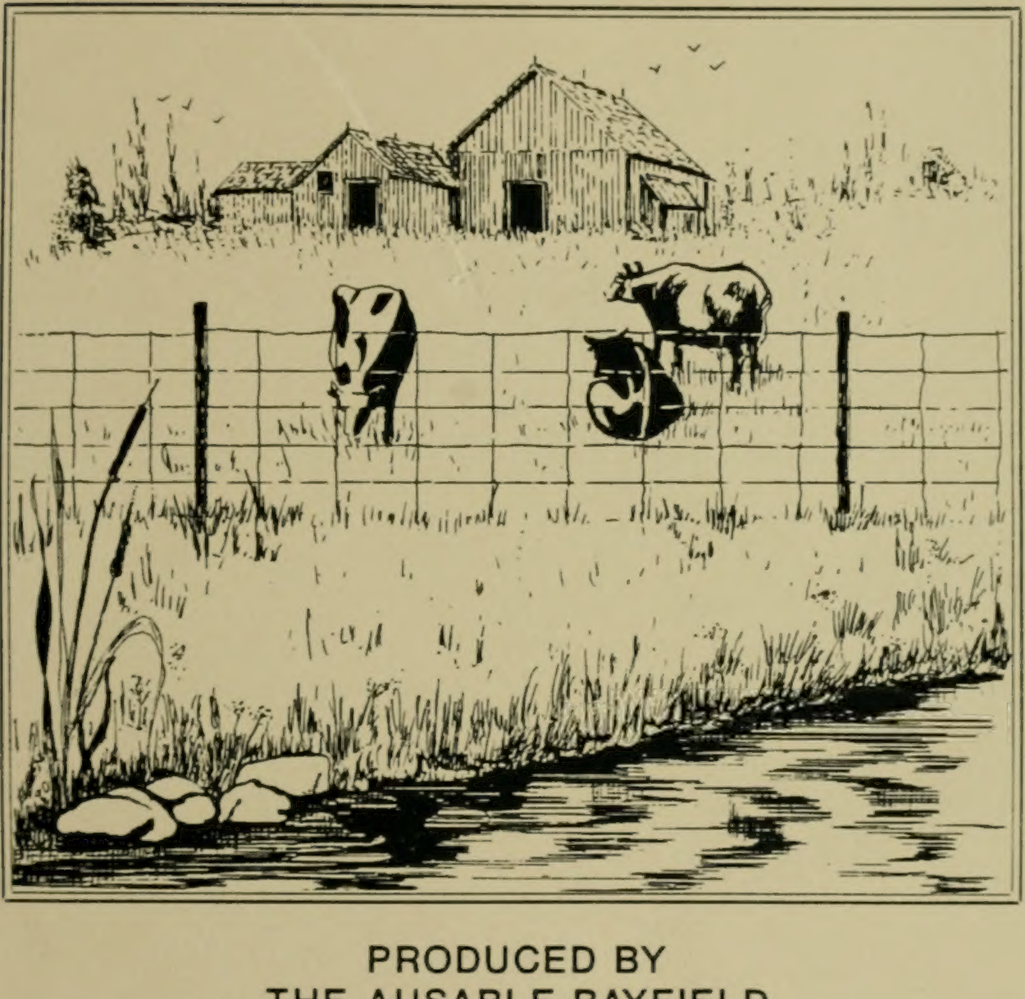
CLEAN UP RURAL BEACHES (CURB) PLAN

FOR LAKE HURON BEACHES IN THE AUSABLE BAYFIELD WATERSHED



PRODUCED BY
THE AUSABLE BAYFIELD
CONSERVATION AUTHORITY

FOR THE ONTARIO MINISTRY OF THE ENVIRONMENT

ISBN 0-7729-8652-5

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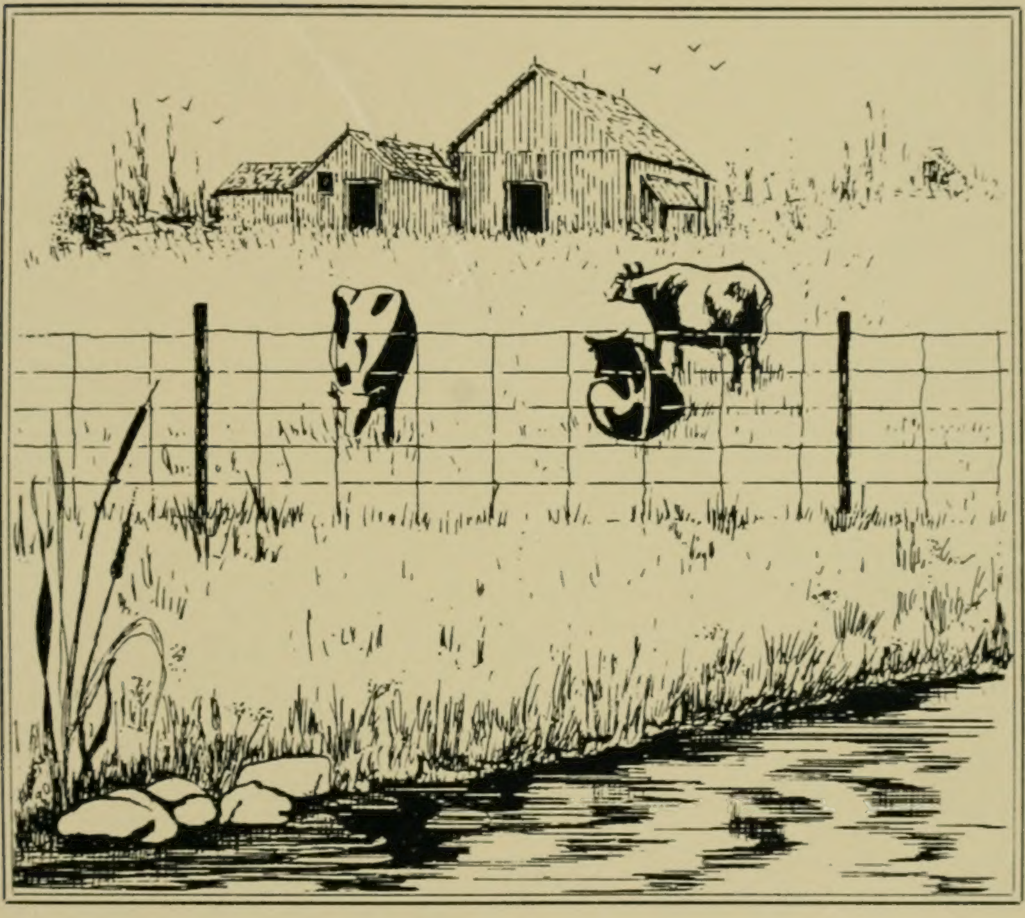

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DISCLAIMER

This report has been reviewed by the local Technical Steering Committee and approved for publication. Approval does not necessarily signify that the contents reflect the position and/or policies of individual agencies.

FOREWORD

This report is one of a series produced under the Provincial Rural Beaches Program. The objective of the Program is to identify the relative impact of pollution sources, and develop a course of action leading to the restoration and long term maintenance of acceptable water quality at provincial rural beaches.

Significant enrichment and bacterial contamination in southern Ontario rivers and lakes originates from rural sources. The discharge of waste material to streams can result in elevated bacterial concentrations, nuisance algae blooms, fish kills, and present a potential health hazard to humans and livestock using the water. Watershed studies have found that a multitude of pollution sources and pathways may affect beaches in Ontario. These include:

1) Urban sanitary and stormwater runoff,
2) Direct livestock manure access to watercourses,
3) Inadequate manure management practices,
4) Direct discharge of milkhouse wastes,
5) Contaminated field tile systems, and
6) Faulty septic systems

The impact upon beaches of any of these sources, either singly or in combination, can range from a few days of elevated concentrations to complete seasonal closures.

Numerous beach closings in 1983 and 1984, drew public and government attention to the severity of this water quality problem. In 1985, the Ontario Ministry of the Environment's (MOE) Water Resources Branch formulated the Provincial Rural Beaches Strategy Program. Directed by the Provincial Rural Beaches Planning and Advisory Committee, it includes representatives from MOE, Ministry of Agriculture and Food (OMAF), and Ministry of Natural Resources (MNR).

With financial and technical assistance from the MOE, local Conservation Authorities carry out studies under the direction of a local technical steering committee. Chaired by an MOE regional staff, the committees typically include representation from OMAF, MNR, the Medical Officer of Health, Conservation Authority, the local Federation of Agriculture, and a local farmer. The chairs of the local committees assure communication between all the projects by participating on the Provincial Committee.

The primary objective of each local study is to identify the relative impact of pollution sources, their pathways to beaches, and to develop a Clean Up Rural Beaches (CURB) plan specific to the watershed upstream of each beach. The CURB plan develops remedial strategy options and respective cost estimates for each beach through:

1) Field inspections,
2) Farmer consultations,
3) Water quality monitoring, and
4) Basic mathematical modelling techniques.

Recommended actions will include both measures for specific beaches and broader scale Provincial measures based on cumulative results of component studies.

The following related research projects were also MOE funded and undertaken by various Conservation Authorities to improve our understanding of bacterial and nutrient dynamics:

1) Insitu bacterial survival studies determine longevity: in watercourses, offshore of beaches, in sediments, and in milkhouse washwater tiles.

2) Biotracer studies determine the speed and nature of travel for bacteria introduced into a watercourse.

3) A liquid manure spreading study examines bacterial movement through the soil column and exiting field tile drains.

4) A target sub-basin study evaluates the effectiveness of a watershed with comprehensive remedial measures.

Numerous demonstration farms have been established with the cooperation of local farmers to display innovative management practices. Research continues on their effectiveness at improving water quality.

Comments and/or questions on this report are welcome. Please send written comments to:

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AUSABLE BAYFIELD CONSERVATION AUTHORITY

CLEAN UP RURAL BEACHES (C.U.R.B.) PLAN

Prepared by:

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and
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1989

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SUMMARY

This report represents the Clean Up Rural Beaches (C.U.R.B.) Plan for the Ausable Bayfield Conservation Authority's (A.B.C.A.) Target Sub-basin Study. The objective of this Plan is to protect water quality at Grand Bend beaches and by extension all Lake Huron beaches within the A.B.C.A. jurisdiction. Recommendations include information extension to increase resident awareness of sources of rural sources of contamination, encouragement of best septic waste and manure management practices, and grants to eliminate contamination of A.B.C.A. watercourses by livestock access and milkhouse waste discharges.

The goal is to reduce fecal coliform bacteria and total phosphorus loads delivered to A.B.C.A. watercourses and subsequently to Lake Huron. The C.U.R.B. model estimates these contaminant loads from rural sources within each of the 63 subwatersheds of the A.B.C.A. by a series of algorithms.

Faulty domestic septic systems are estimated to be one of the largest sources of both fecal coliform bacteria and total phosphorus delivered to Lake Huron. Contaminated runoff from winter-spread manure is another significant source of both forms of contamination. Soil erosion is also a significant source of phosphorus delivered to Lake Huron.

Small watersheds adjoining Lake Huron deliver the greatest bacteria loads to Lake Huron, not necessarily those with the largest area or the highest number of livestock operations. This is due to attrition during travel to Lake Huron due to natural causes.

Preliminary analysis indicates that repair of faulty domestic septic systems would provide the most cost-effective means of eliminating bacteria delivered to Lake Huron and would also be highly effective in the removal of phosphorus from rural drains. Elimination of milkhouse waste discharges to drains is the most cost-effective way to reduce phosphorus loadings in A.B.C.A. watersheds.

Where possible, information unique to the A.B.C.A. watershed has been incorporated into C.U.R.B. algorithms to attempt an accurate description of contaminant sources. Further study of travel times within A.B.C.A. watersheds and examination of watershed discharge plumes will aid cost-effectiveness studies of remedial activities.

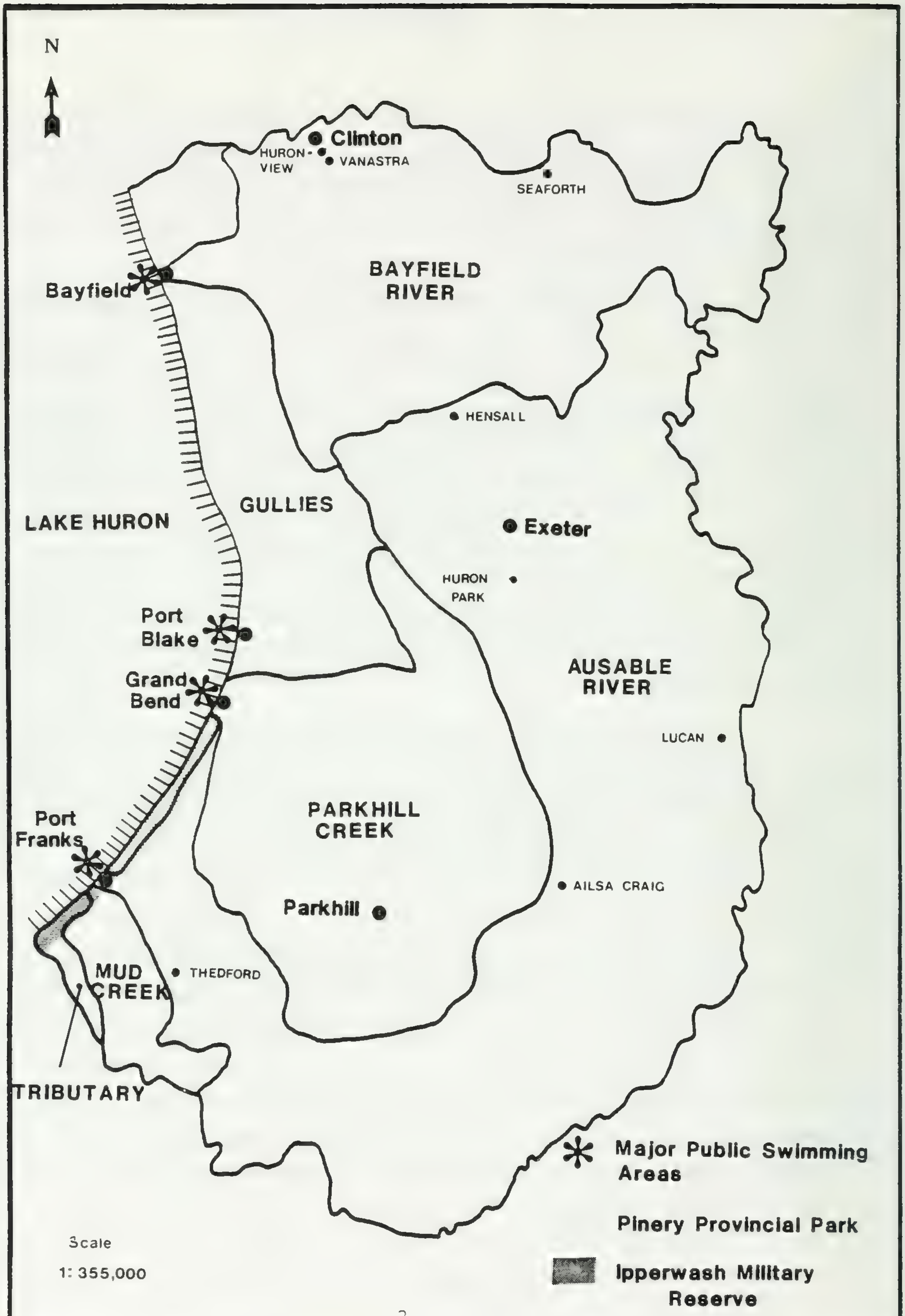
1.0 INTRODUCTION

In the early 1980's poor water quality forced beach closures across Ontario. These closures not only reflected increased health risk as a result of deteriorating water resources but posed significant economic losses for the recreation industry. As a result of these concerns, the Ontario Ministry of the Environment (O.M.E.) initiated the Rural Beaches Strategy Program.

The Ausable Bayfield Conservation Authority (A.B.C.A.) Watershed Plan identifies water quality as a priority A.B.C.A. program. The most significant beach areas of the A.B.C.A. are located on the shores of Lake Huron. The Pinery Provincial Park, Port Blake Conservation Area, and the lakeshore villages of Port Franks, Grand Bend and Bayfield feature 10.3 km of Lake Huron's premier beaches, 11.2 percent of the A.B.C.A.'s 60 km of Lake Huron shoreline. The Ipperwash Military Reserve has 3.2 km (5.3 percent) of Lake Huron shoreline but does not have public access. The remaining 46.6 km of shoreline has private access. Swimming is available at some inland conservation areas. These are monitored by local Public Health Units. None have been closed due to high bacteria concentrations exceeding O.M.E. guidelines or algal blooms in recent years. Map 1 locates Lake Huron's public swimming areas and delineates the A.B.C.A.'s major drainage watersheds.

In the summer of 1983, beaches at Grand Bend were closed in midsummer due to poor bacterial water quality. In 1984 and 1985, the O.M.E. conducted water quality studies and reported that rivers and creeks carried fecal material to beach areas from watersheds. The majority of bacterial loadings originated from tributaries draining agricultural watersheds, apparently as a result of normal farming practice (O.M.E., 1984).

The A.B.C.A. has been involved in water quality studies since 1982. In 1983, the Manure Management Awareness Program (M.M.A.P.) was carried out in co-operation with the O.M.E. Southwestern Region. M.M.A.P. staff monitored water quality in rural drains within the A.B.C.A. watersheds as well as providing technical assistance to livestock farmers to reduce negative impacts on water quality by their operations. A farm survey was carried out by the A.B.C.A. to determine potential risk of contamination to watercourses from livestock operations. Information compiled included herd size, manure storage facilities, livestock access to drains, milkhouse waste discharges to drains and potential contamination of runoff by manure. This program continued until the spring of 1988. Although separate from the Rural Beaches Program, the M.M.A.P.



Map 1. Watersheds of the Ausable Bayfield Conservation Authority

provided valuable background information for the C.U.R.B. report. The A.B.C.A.'s Target Sub-basin Study (T.S.S.) is a component of the Provincial Rural Beaches Strategy Program. The goal of the T.S.S. is to determine whether it is possible to significantly improve the quality of water discharged from livestock farms. From 1986 to 1988, the T.S.S. has installed improved manure storage facilities and actively encouraged better manure management practices (B.M.P.'s) in a target sub-watershed of Parkhill Creek.

An objective of the Provincial Beaches Strategy Program and the purpose of this report is the development of a strategy to ensure good water quality at Ontario beaches. This is the Clean Up Rural Beaches (C.U.R.B.) Plan. Development of this plan incorporated the use of the Pollution from Livestock Operation's Predictor (P.L.O.P.) model developed for the O.M.E. by Ecologistics Ltd. and subsequently modified by Beaches Strategy staff at a 3 day intensive Workshop at Kempenfelt Bay in July, 1988.

2.0 THE C.U.R.B. MODEL

The C.U.R.B. model utilizes algorithms to estimate fecal coliform bacteria and total phosphorus contaminant loads generated in rural areas and delivered to beaches. Algorithms were developed to address the following sources:

1) milkhouse waste discharges to drains
2) livestock access to open drains
3) exposed barnyard - feedlot areas
4) manure stack runoff
5) winter-spread manure runoff
6) summer-spread manure runoff
7) domestic septic discharges to drains

While numbers of bacteria transported by drains are generally expected to decline over distance (decay) due to natural attrition, for the purposes of this report phosphorus loads do not decline over distance.

Wherever possible, locally derived values (for example contaminant concentrations in runoff, discharges, and septic failure rates) were utilized in order to make predicted loads as accurate as possible. It is planned to calibrate the A.B.C.A. C.U.R.B. model with T.S.S. results.

The C.U.R.B. algorithms required information specific to the A.B.C.A. watershed. M.M.A.P. survey information collected from 1983 to 1988 was utilized in the C.U.R.B. model. The following sections detail treatment of the existing information base utilized in the A.B.C.A. C.U.R.B. model.

2.1 Farm Surveys

Table 1 details the numerical breakdown of livestock operations with potential to contaminate watercourses by sub-watershed. The number of detailed surveys is given in brackets.

One hundred and seventy-one (171) farms were surveyed in some detail during the M.M.A.P. A total of 826 livestock operations in the A.B.C.A. watershed were identified as having pollution potential. These 826 were separated into high and low potential

TABLE I: The Number of Farms Having Pollution Potential and the Number of Completed Surveys, by Sub-watershed

( ) No. of farms for which a survey was conducted

Ausable Watershed

Sub-Watershed	No. of Low Potential Farms		No. of High Potential Farms	
1	24	(4)	7	(6)
2	15	(1)	4	(3)
3	13	(3)	4	(0)
4	0	(0)	0	(0)
5	16	(2)	0	(0)
6	14	(0)	1	(1)
7	7	(0)	5	(2)
8	15	(2)	5	(1)
9	7	(2)	4	(2)
10	3	(1)	1	(1)
11	17	(2)	10	(7)
12	10	(1)	1	(1)
13	15	(2)	10	(3)
14	11	(0)	8	(4)
15	1	(0)	1	(0)
16	13	(2)	5	(1)
17	0	(0)	0	(0)
18	4	(0)	1	(0)
19	12	(1)	2	(1)
20	12	(0)	4	(3)
21	11	(0)	0	(0)
22	5	(0)	5	(1)
23	13	(1)	5	(3)
24	1	(0)	0	(0)
25	33	(4)	16	(11)
26	10	(1)	4	(3)
27	9	(1)	3	(0)
28	10	(0)	4	(2)
29	0	(0)	0	(0)
30	7	(1)	0	(0)
31	0	(0)	0	(0)
32	0	(0)	0	(0)
	308	(31)	110	(56)

Bayfield Watershed

Sub-Watershed	No. of Low Potential Farms		No. of High Potential Farms	
1	13	(0)	1	(1)
2	8	(0)	4	(3)
3	10	(1)	1	(0)
4	10	(3)	3	(3)
5	3	(0)	1	(1)
6	5	(0)	1	(1)
7	16	(4)	3	(3)
8	11	(6)	5	(1)
9	25	(1)	2	(0)
10	0	(0)	0	(0)
11	7	(2)	2	(0)
12	12	(2)	0	(0)
	120	(19)	23	(13)

Parkhill Watershed

Sub-Watershed	No. of Low Potential Farms		No. of High Potential Farms	
1	35	(5)	10	(5)
2	8	(1)	5	(4)
3	3	(0)	1	(0)
4	24	(2)	6	(3)
5	1	(0)	1	(1)
6	8	(0)	0	(0)
7	10	(1)	0	(0)
8	5	(1)	1	(0)
9	12	(3)	3	(1)
10	2	(1)	0	(0)
11	7	(2)	6	(2)
12	10	(1)	0	(0)
13	4	(0)	0	(0)
	129	(17)	33	(16)

Mud Creek Watershed

Sub-Watershed	No. of Low Potential Farms		No. of High Potential Farms	
1	10	(0)	3	(2)
2	0	(0)	0	(0)
3	12	(3)	1	(1)
	22	(3)	4	(3)

Gullies and Tributary Watersheds

Sub-Watershed	No. of Low Potential Farms		No. of High Potential Farms	
Gn	8	(0)	0	(0)
G	61	(11)	6	(2)
T	2	(0)	0	(0)
	71	(11)	6	(2)

groups based upon: distance to an open watercourse, factors conducive to the transport of nutrients to a watercourse, the intensity of the livestock operation and the possibility of livestock access to a watercourse (Balint, 1984, pp 7-8). One hundred and seventy-six (176) livestock operations were considered to have a high potential for contamination, the remaining 650 low potential. Ninety detailed surveys (53 percent) were completed on high potential farms. Most high potential farms met all the criteria detailed above while low potential farms exhibited little physical evidence of surface transport of contaminants to watercourses by the livestock operations activities.

Information from both high and low potential farms was utilized in C.U.R.B. algorithms. In order to estimate total loads for each sub-watershed, compensation had to be made for incomplete survey information. For these, typical A.B.C.A. livestock farm profiles (such as numbers and types of livestock) were developed from M.M.A.P. surveys and T.S.S. remedial project farms. This information was used in the development of contaminant loads listed in Appendix I.

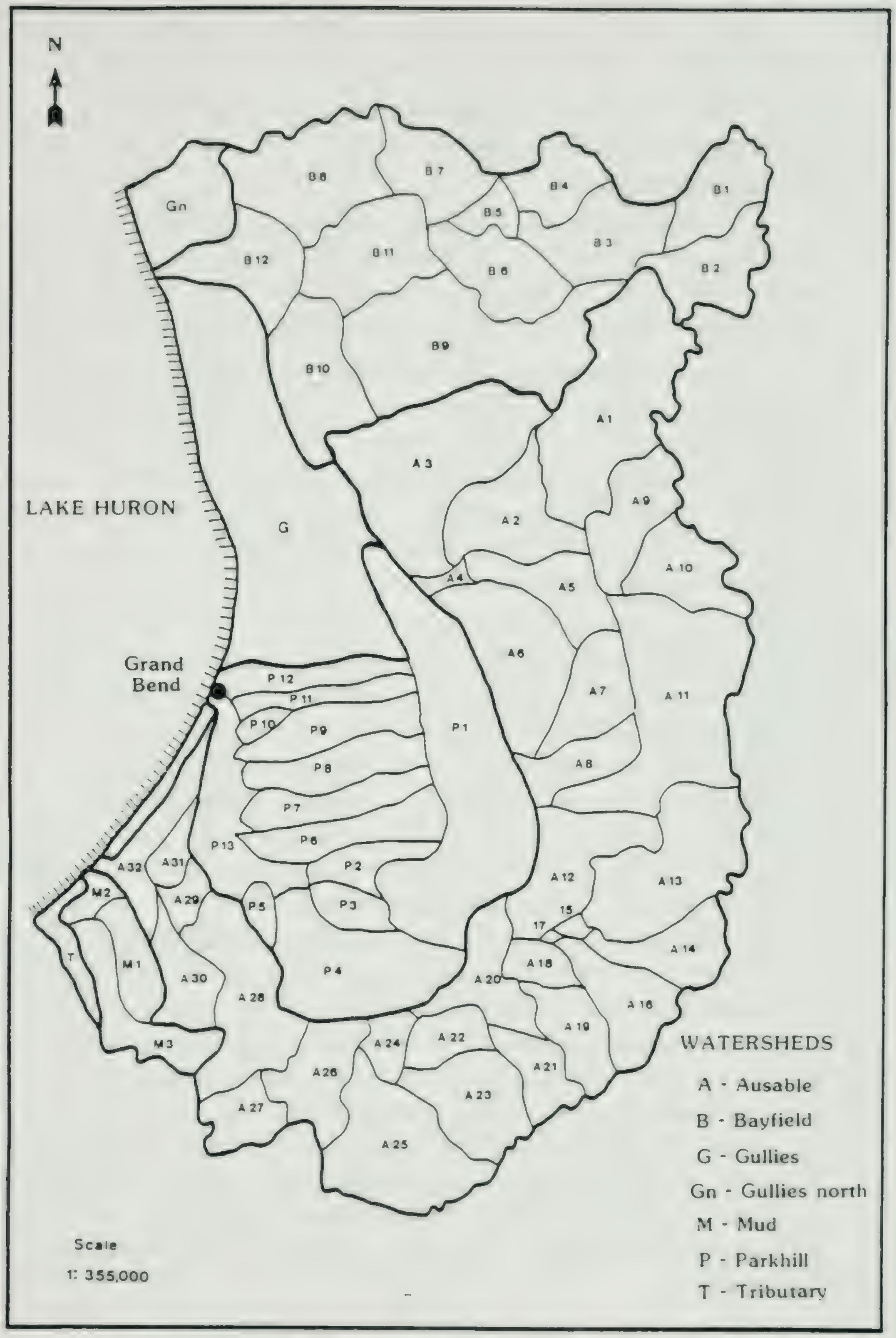
2.2 Contaminant Travel Times

Contaminant travel times were required for beach delivery calculations of sub-watershed bacteria loads.

High flow travel times from each sub-watershed were calculated by Dillon (1975) using the "time of concentration". This is the time required for water to flow from the most remote location in a sub-watershed to its outlet when soils are saturated. Contaminant travel times from the centroid of each sub-watershed were derived by halving Dillon's "time of concentration".

High flow travel times from the centroid of each sub-watershed to Lake Huron were calculated by summing the travel times for downstream sub-watersheds plus the travel time from the centroid of that sub-watershed. This approximates travel times when rain saturates soils and generates runoff that may carry contaminants to water courses.

Low flow travel times were determined by the observed movement of tracer bacteria injected into the headwaters of the Desjardine Drain in 1987 and 1988 (sub-watershed P11, Map 2). Travel times when unsaturated soil conditions existed were determined to be 5.75 times longer than the time of concentration (high flow or event) times determined by Dillon. This factor was applied to all A.B.C.A. sub-watersheds.



Map 2. Sub-watersheds of the Ausable Bayfield Conservation Authority

Low flow travel times are used to calculate beach contaminant loads from sources that continuously discharge to watercourses (such as private septic systems).

Travel times for each sub-watershed are listed in Appendix 2.

2.3 Watershed Contaminant Loadings

2.3.1 Agricultural Loadings

Guidelines used to estimate contaminant loadings were developed at the Clean Up Rural Beaches (C.U.R.B.) Plan Workshop (Kempenfelt). C.U.R.B. contaminant concentrations used for A.B.C.A. watersheds were later modified as a result of discussions with U.T.R.C.A. and M.V.C.A. Beaches staff. These are shown in Table 2.

Agricultural contaminant loadings are derived from two source groups: continuous and pulse. Sources that deliver contaminants to watercourses independent of weather are continuous discharge sources. Septic, milkhouse, sewage treatment facilities discharges and cattle access sites are examples of continuous discharge sources. Pulse discharges are dependent upon rainfall generating surface runoff (which may become contaminated) captured by tile drains and watercourses. Barnyards, feedlots, unroofed manure storages, and unincorporated field spread manure are examples of pulse sources.

Where specific information (i.e. manure stacks and feedlot sizes) were not available from M.M.A.P. surveys, it was necessary to use estimates based upon data obtained during the Target Sub-basin Study (T.S.S.). The general guidelines upon which the estimates are based are as follows:

1) Where M.M.A.P. survey information is unavailable, milkhouse wastes are assumed to be discharged untreated to drains on 67 percent of all dairy operations.
2) Livestock access to drains, where noted in M.M.A.P. surveys was assumed to be 180 days in duration. In this application of the C.U.R.B. model, only livestock animals are used to estimate fecal loadings directly to drains.
3) Actual dimensions of manure stacks, barnyards and intensively used animal pastures are used where possible. Average values from Target Sub-basin farms are used in absence of M.M.A.P. survey information. As all Target Sub-basin remedial projects required eavestroughing, roof areas are included in the average feed lot size.
4) All swine and poultry operations with liquid manure handling facilities are assumed to have neither barnyard nor manure stack runoff, unless other livestock animals are present. Where both solid and liquid waste handling systems were noted, full average sized lots and manure stacks were assumed present. Semi-solid waste systems with retaining walls were treated as liquid systems. Delivery of liquid runoff bearing contaminants from manure stacks and feedlots to drains was assumed to be 80 percent.

TABLE 2: Contaminant Concentrations used in A.B.C.A.
C.U.R.B. Algorithms

Source	Fecal Coliform Bacteria	Total Phosphorus
Milkhouse Wastes	2000 per litre (C.U.R.B.)	0.000168 kg per litre (P.L.O.P. p. 42)
Livestock Access	8.9×10^8 per defecation (U.T.R.C.A.)	1.2×10^{-3} kg per defecation (P.L.O.P. p.38)
Feedlot Runoff	5.0×10^9 per ha-mm (A.B.C.A.)	85×10^{-6} kg per litre (P.L.O.P. p. 25)
Spreading	3×10^{10} fecal coliform per kg (C.U.R.B.)	0.58 kg per tonne (P.L.O.P. p. 34)
Septic	1×10^7 fecal coliform per litre (A.B.C.A.)	30.8×10^{-6} kg per litre (A.B.C.A.)

5) Exponential decay of bacteria was expected to take place in the manure storage period. It was assumed that farms spreading manure in winter would do so more frequently, thus allowing for less decay time in the manure stack than for summer. Assuming an average 15 day stack time in winter and 45 day stack time in summer, decay rates may be 1.5 and 2.0 logs/day respectively (Kress and Gifford, 1984).
6) Exponential decay of bacteria in field-spread manure is expected to occur through dessication and exposure to sunlight. Surviving bacteria are transported to drains when runoff events are caused by rainfall. These events are expected to occur on the average of once every two weeks. Decay of bacteria (e^{-kt}) is estimated to be 63 percent over two weeks (average 7 days) where 0.066 is the decay constant for manure exposed to sunlight. (R. Fuller, personal communication, 1989 and P.L.O.P., page 35).
7) Bacteria survival experiments conducted in the Desjardine drain during June, July and August 1988 by the O.M.E. - S.W.R. and A.B.C.A. Beaches staff yielded an average die off rate of 0.38 logs per day. This value was used in C.U.R.B. algorithms when estimating sub-watershed bacterial load delivered to Lake Huron beaches by livestock farms, faulty septic systems and sewage treatment facilities.
8) Domestic septic system failures were found in 4 out of 5 (80 percent) livestock farms undergoing remedial work in the Target Sub-basin. Faulty septic systems were either directly discharging to, or causing surface ponding resulting in contamination of working drain tiles. Of 15 dwellings in the T.S.S. 9 (60 percent) required repair. It was felt that the high (90 percent) grant rate offered to repair led to a more accurate accounting of septic contamination in the T.S.S. and that 60 percent may be an appropriate estimate of septic failure in the A.B.C.A. watershed rather than the 30 percent failure rate suggested by the C.U.R.B. model.

The development of a profile of the average watershed livestock farm has already been noted. Potential contamination of drains by milkhouse wastes and excessive manure spreading is interpreted from M.M.A.P. criteria to be comparable for both high and low potential farms. Livestock access, feedlot, barnyard and manure stack runoff has less impact on low potential farms, due to partial control or buffering as evaluated by the M.M.A.P. surveyor. C.U.R.B. algorithms also allow for reduced contaminant delivery to drains due to local site conditions. As noted M.M.A.P. surveys divided potentially contaminating livestock operations into two categories: 1) high and 2) low potential operations. High potential farms exhibited evidence of manure reaching the watercourse in the past. Farms with pollution potential but little evidence of manure reaching the watercourse were classified as having low potential contamination. Farms without livestock and appearing to be cash crop were not ranked nor included in the inventory (Balint 1984). To address this two level ranking system in the A.B.C.A. C.U.R.B. summary, all low potential farms had pollutant delivery to be estimated at 10 percent of the total potential for manure runoff from stacks, feedlots, barnyards and pastures. Delivery to drains from milkhouses, cattle access and potential over-spreading from both winter and summer manure spreading was assumed to be the same for both high and low potential farms.

The contribution of native bacteria bound to soil particles eroded by rainfall to watercourses is not addressed by this model.

2.3.2 Sewage Treatment Facilities

Loadings contributed by sewage treatment facilities were also determined and delivery to beaches estimated. There are 12 sewage treatment facilities in the A.B.C.A. watersheds, 7 of which are lagoons. The lagoons are generally discharged once per year under high flow conditions which resemble pulse runoff events. Other sewage treatment facilities continuously discharge similar to septic systems or milkhouse wastes. Thus, sewage treatment facilities were divided into either pulse or continuous discharge groups. Available water quality and discharge data allowed loading estimates from these sources. A.B.C.A.'s two municipally operated facilities in Exeter and Clinton are not required to collect bacteria samples, so for the purposes of this report an estimated mean concentration of 200 F.C./100ml was used (Kutas, W. and Turnbull, R., M.O.E.-S.W.R., personal communication 1988). Table 3 summarizes the predicted loads from A.B.C.A. watershed sewage treatment facilities.

2.3.3 Rural and Lakeshore Septic System Contamination

7,347 homes are serviced by septic systems in the watersheds of the A.B.C.A., 1038 of which are lakeshore homes or cottages. Numbers of septic systems in each sub-basin were estimated from 1:50,000 topographic maps and are presented in Table 4. The Target Sub-basin remedial project farms had an average 3.5 persons per dwelling. This occupancy rate was applied to the A.B.C.A. watersheds. Domestic waste water volumes may approach the 75 Imperial gallons (340 litres) per person per day design specification for septic systems regulated by the Huron County Health Unit (J. McKinnon, 1988 personal communication).

Lakeshore cottages were considered separately due to the potential immediate impacts from faulty septic systems. Since these are seasonal dwellings, loads are reduced by 50 percent per year to reflect one-half year of occupancy. Due to the proximity of these systems to Lake Huron, bacteria load decay due to travel time is estimated to be negligible. As more cottages are converted from seasonal dwellings to permanent residences there will be greater pressure placed on existing septic waste disposal systems, increasing potential contamination of beaches along Lake Huron shoreline.

TABLE 3: Summary of Fecal Coliform and Total Phosphorous Delivery From Sewage Treatment Plants and Lagoons to Beach

Location of Sewage Treatment Plant Or Lagoon	Sub-watershed Reference	Type of Discharge	Travel Time To Beach Days	Total Load of Fecal Coliform Per Year	Total Load of Total Phosphorous Per Year (kg)	Load of Fecal Coliform Delivered to Lake Huron	% of Fecal Coliform Delivered to Lake Huron
Ausable							
Exeter	A2	Continuous	17.0	1.58×10^{12}	330	2.5×10^{9}	0.03
Hensall	A3	Pulse	3.1	1.2×10^{10}	176	3.7×10^{9}	30.8
Huron Park	A6	Continuous	14.8	3.2×10^{11}	910	1.2×10^{9}	0.38
Lucan	A11	Pulse	2.4	8.1×10^{12}	119	3.3×10^{12}	40.2
Ailsa Craig	A13	Continuous	12.9	2.46×10^{11}	76	1.8×10^{9}	0.35
Thedford	A32	Pulse	0.24	1.84×10^{11}	36	1.7×10^{11}	30.8
					1647	3.5×10^{12}	
Bayfield							
Seaforth	B4	Pulse	0.64	9.7×10^{11}	320	7.6×10^{11}	78.4
Vanastra	B8	Continuous	1.32	3.5×10^{12}	86	2.1×10^{12}	60.6
Clinton	B8	Continuous	1.32	1.52×10^{12}	530	9.2×10^{11}	52.4
Huronview	B8	Pulse	0.23	3.2×10^{12}	110	2.0×10^{12}	[illegible]
					1046	5.8×10^{12}	
Parkhill							
Parkhill	P3	Pulse	0.76	2.03×10^{10}	174	1.5×10^{10}	[illegible]
Grand Bend	P13	Pulse	0.35	7.22×10^{10}	220	6.3×10^{10}	87.3
					394	6.32×10^{12}	
			TOTAL	2.0×10^{13}	3087 kg	1.6×10^{13}	

Continuous Discharge = low flow

Pulse Discharge = low flow

TABLE 4: Estimated Numbers of Septic Systems by Sub-watershed

Ausable Watershed

Sub-watershed	# of Septic Systems
A 1	235
A 2	153
A 3	214
A 4	2
A 5	102
A 6	214
A 7	45
A 8	95
A 9	96
A 10	96
A 11	164
A 12	82
A 13	173
A 14	56
A 15	10
A 16	95
A 17	11
A 18	39
A 19	59
A 20	44
A 21	30
A 22	36
A 23	68
A 24	7
A 25	95
A 26	64
A 27	245
A 28	96
A 29	32
A 30	65
A 31	89
A 32	121
	2933

Bayfield Watershed

Sub-watershed	# of Septic Systems
B 1	179
B 2	68
B 3	92
B 4	58
B 5	57
B 6	49
B 7	69
B 8	163
B 9	258
B 10	125
B 11	153
B 12	179
	1450

Parkhill Watershed

P 1	272
P 2	34
P 3	64
P 4	86
P 5	13
P 6	34
P 7	57
P 8	94
P 9	70
P 10	11
P 11	42
P 12	51
P 13	122
	950

Mud Creek Watershed

M 1	53
M 2	16
M 3	37
	166

Lakeshore, Gullies and Tributary Watersheds

G(north)	181
G(south)	568
Lakeshore	1038
Tributary	61
	1848

2.3.4 Wildlife Impacts

Loadings from wildlife were not quantified but considered equivalent for all sub-watersheds. Their impact is assumed to be minimal (C.U.R.B. 1988).

2.3.5 Spills

Manure spills were presumed to be the result of inadvertent or excessive applications of manure. For the purposes of the A.B.C.A. model it was expected that spills could be included in contaminant loads generated by winter and summer spreading. The provision of adequate storage facilities, education and operator awareness would minimize this problem.

Five incidences of excessive application of liquid manure were reported in the A.B.C.A. watersheds in 1988, none of which resulted in a fish kill (Hutt 1989; Farrel 1989; Thompson 1989 personal communication). The magnitude of those spills are not known. Two of the spills were located in Middlesex County and had direct access to a drain flowing into the Ausable River. The remaining three, located in Huron County did not have direct access to a drain. Consequently manure spills were considered to have minimal impact on contaminant loads in the A.B.C.A. watercourses.

3.0 A.B.C.A. C.U.R.B. MODEL RESULTS

The C.U.R.B. algorithms estimate contaminant loads. These loads are listed for each sub-watershed of the A.B.C.A. in Appendix 1. Figures 1 to 9 summarize these results. Figure 1 illustrates bacteria loads produced by all sources and the portions eventually delivered to Lake Huron. Figure 2 compares delivered bacteria loads. Figures 3 to 9 indicate sources of contaminant bacteria delivered to Lake Huron. Figure 10 summarizes sources of total phosphorus delivered to A.B.C.A. watercourses. Figures 11 to 21 (Appendix 5) illustrate continuous and pulse source contaminant discharges generated and delivered to Lake Huron.

3.1 Bacteria Loadings

Watershed size and the number of livestock operations appears to be less important than time required to flow to Lake Huron. For example, the total bacteria load generated in the Ausable River watershed is considerably greater than any other watershed, yet only 1.4 percent of that total is estimated to reach Lake Huron (Figure 1). This is due to decay of bacteria numbers that occurs during the time required to travel from each sub-watershed to Lake Huron. Appendix 2 indicates that 18.4 days are required to flow from the headwaters of the Ausable River under low flow conditions. It takes 6.33 days from the headwaters of the Bayfield River by comparison which delivers 5 times as much bacteria to Lake Huron (Figure 2). The Ausable River watershed has 50.6 percent (418) of the potentially contaminating livestock operations, 40 percent (2933) of the septic systems and 48 percent (1,173 square kilometers) of the entire A.B.C.A. watershed. The Bayfield River watershed has 17.3 percent of the potentially contaminating livestock farms (143), 19.7 percent (1450) septic systems and 20.7 percent (505 square kilometers) of the A.B.C.A. area.

Lakeshore cottages and Lake Huron Gullies together constitute approximately 12 percent of the total A.B.C.A. watershed drainage area, contain 9.1 percent (75) potentially contaminating livestock operations and 24.5 percent (1787) of all A.B.C.A. domestic septic systems. Gully watercourses are no more than 12 km long while the Ausable River is 145 km in length. Together, the lakeshore cottages and Lake Huron Gullies contribute 69.0 percent of the estimated bacteria load delivered to Lake Huron beaches (Figure 2) primarily from faulty septic systems (Figures 4 and 6). This indicates how each watershed's location and natural flow characteristics affect delivery of bacteria contaminants.

Faulty septic systems and contaminated runoff from spread manure are the largest sources of fecal coliform bacteria delivered to Lake Huron beaches from the Ausable River, Parkhill Creek and Mud Creek watersheds (Figures 7, 8, and 9). These three watersheds deliver only 12.2 percent of the total bacteria load to Lake Huron, approximately two-thirds of the bacteria contaminants delivered by the Bayfield River watershed (Figure 5). Faulty septic systems may deliver 3.3 times more bacteria than winter-spread manure contaminated runoff.

Figures 11 to 21 illustrate fecal coliform bacteria loads contributed to watercourses and the subsequent loads delivered to Lake Huron. It is evident that continuous discharge sources contribute the greatest loads to sub-watershed water courses as well as Lake Huron. Near-lake sub-watersheds in the Ausable Bayfield and Parkhill Creek watersheds (Figures 12, 14, and 16) contribute the greatest share to Lake Huron, even though other sub-watersheds may produce greater total bacteria loads (Figures 11, 13, and 15).

The ability to target shoreline areas that impact priority beaches would assist development of C.U.R.B. strategies. Health Units monitor only public beaches providing no indication of movement of pools of contaminated water along the Lake Huron shoreline.

Increases in water column bacteria concentrations have been observed when wind causes the lake surface to become rough. This is related to resuspension of lake bed sediments (O.M.E. 1984). Bacteria survival (die-off rate) in the beach water column was estimated to be 6 to 7 days (0.92 logs/day) compared to 3 weeks (0.38 logs/day) in the Ausable River water column and at least 2 months (0.06 logs/day) in Lake Huron sediments (O.M.E. 1985). T. Dickinson (1987) indicates that 74.2 percent of the Ausable River's suspended sediment load occurs between February 1 and May 31 and 7.1 percent between June 1 and September 30. C.U.R.B. algorithms do not estimate bacteria loads from this source which appears to be most mobile immediately preceeding summer swimming season. Bacteria transport by suspended sediments in the A.B.C.A. watershed should be investigated further. Long survival periods of bacteria in sediments is important due to potential continuing negative impacts on beach water quality.

Littoral drift affects sediment deposition and transport patterns. Reinders (1988) reports that the net direction of littoral drift on an annual basis is southward from Goderich (past Bayfield, Grand Bend and Port Franks) to the Ipperwash beach area. During short-term event related conditions, littoral drift may be in other directions.

FIGURE 1 : ABCA WATERSHED BACTERIA LOAD

TOTAL AND DELIVERED LOADS TO LAKE HURON

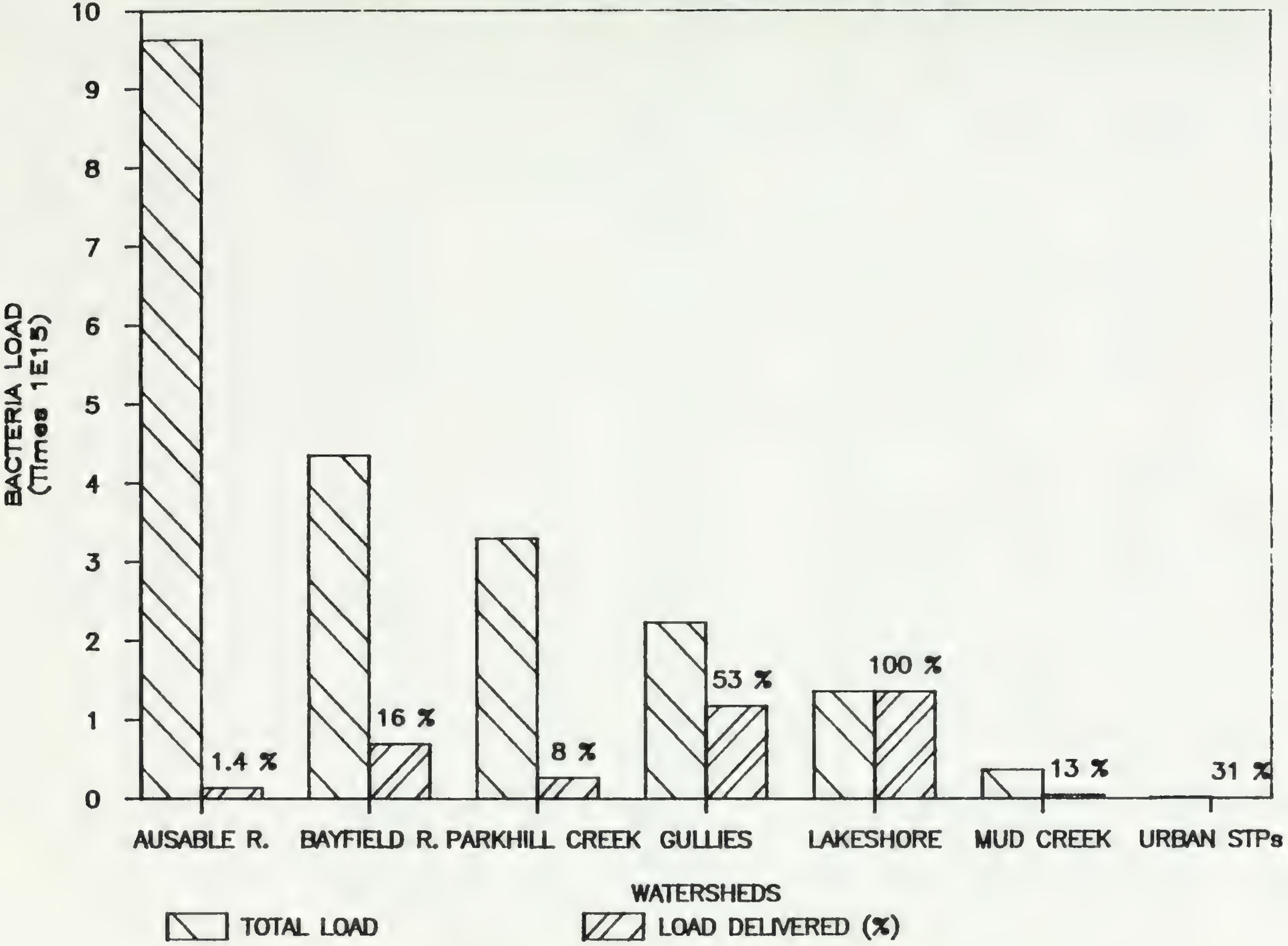


FIGURE 2 : BACTERIA DELIVERED TO LAKE HURON
BY A.B.C.A. WATERSHED

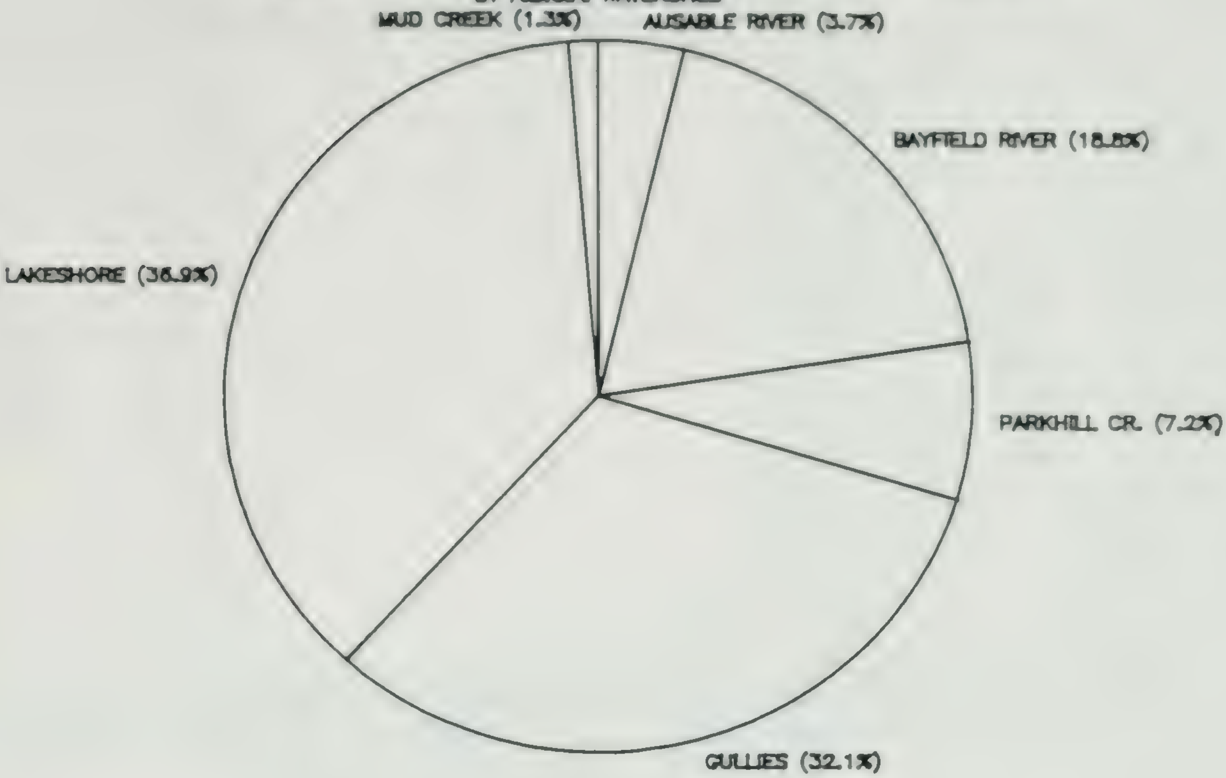


FIGURE 3 : BACTERIA DELIVERED TO LAKE HURON
BY SOURCE FOR ALL A.B.C.A. WATERSHEDS

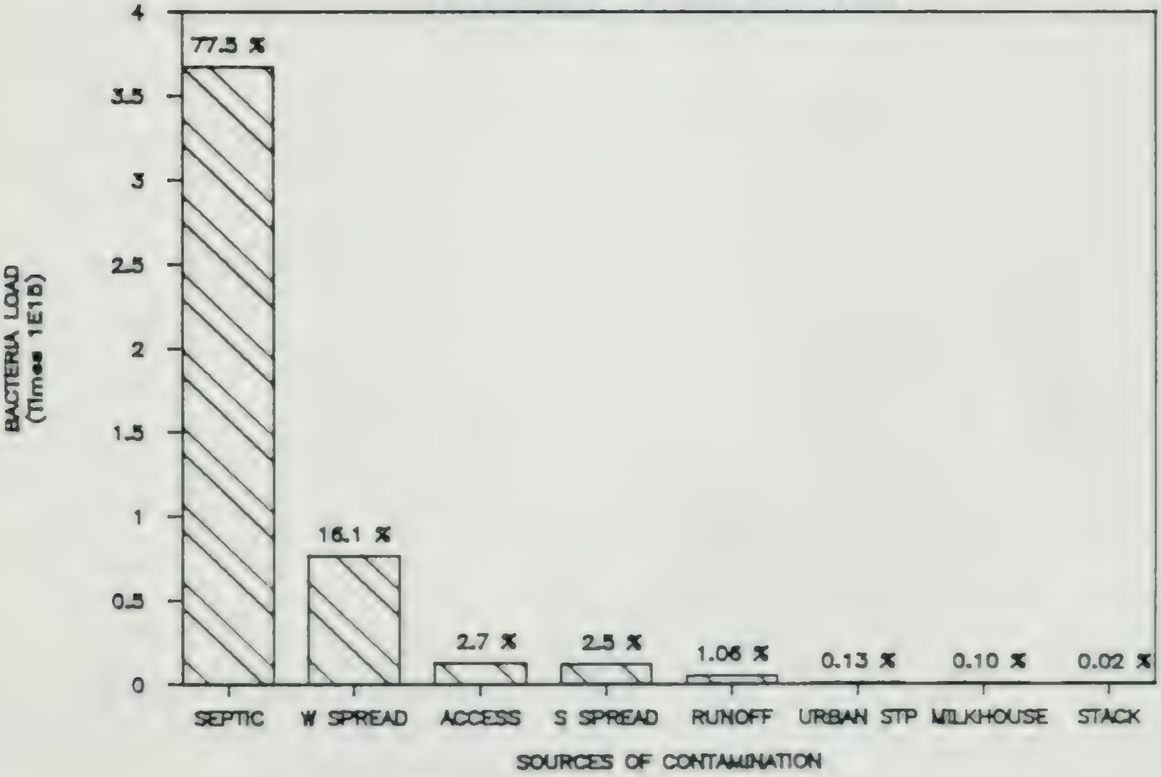


FIGURE 4 : LAKE HURON GULLIES

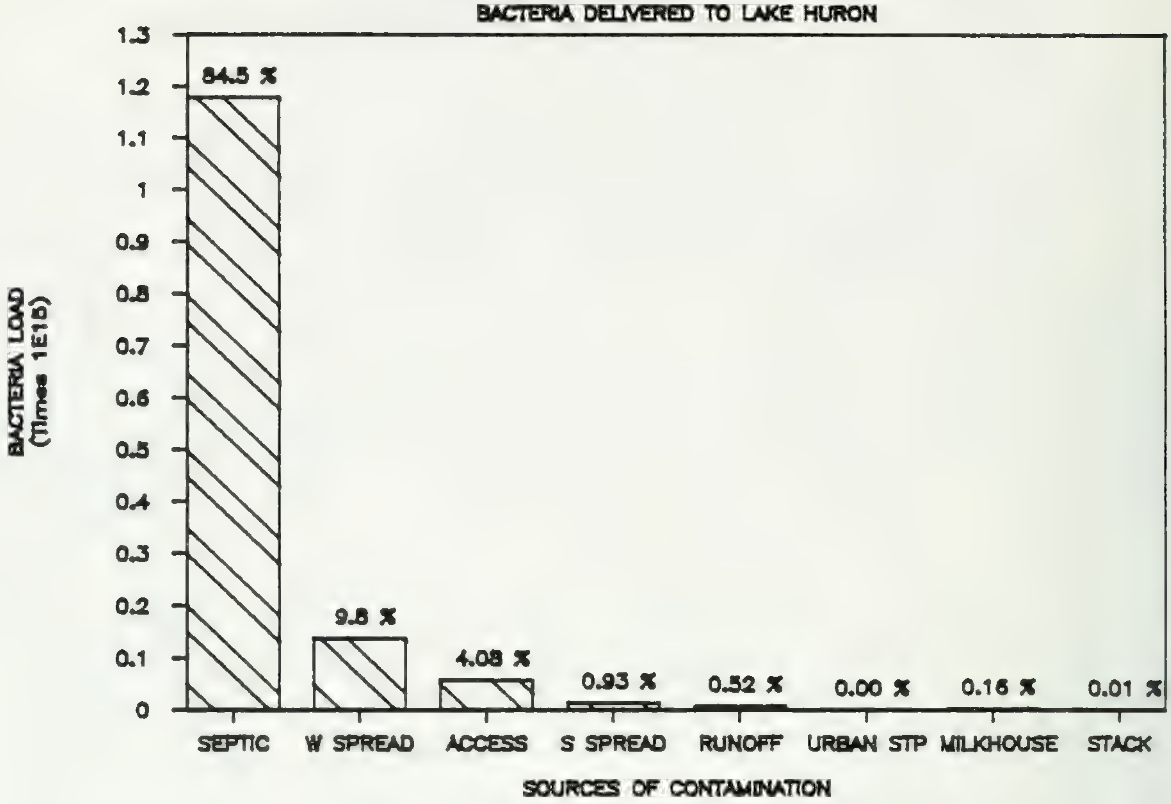


FIGURE 5 : BAYFIELD RIVER WATERSHED

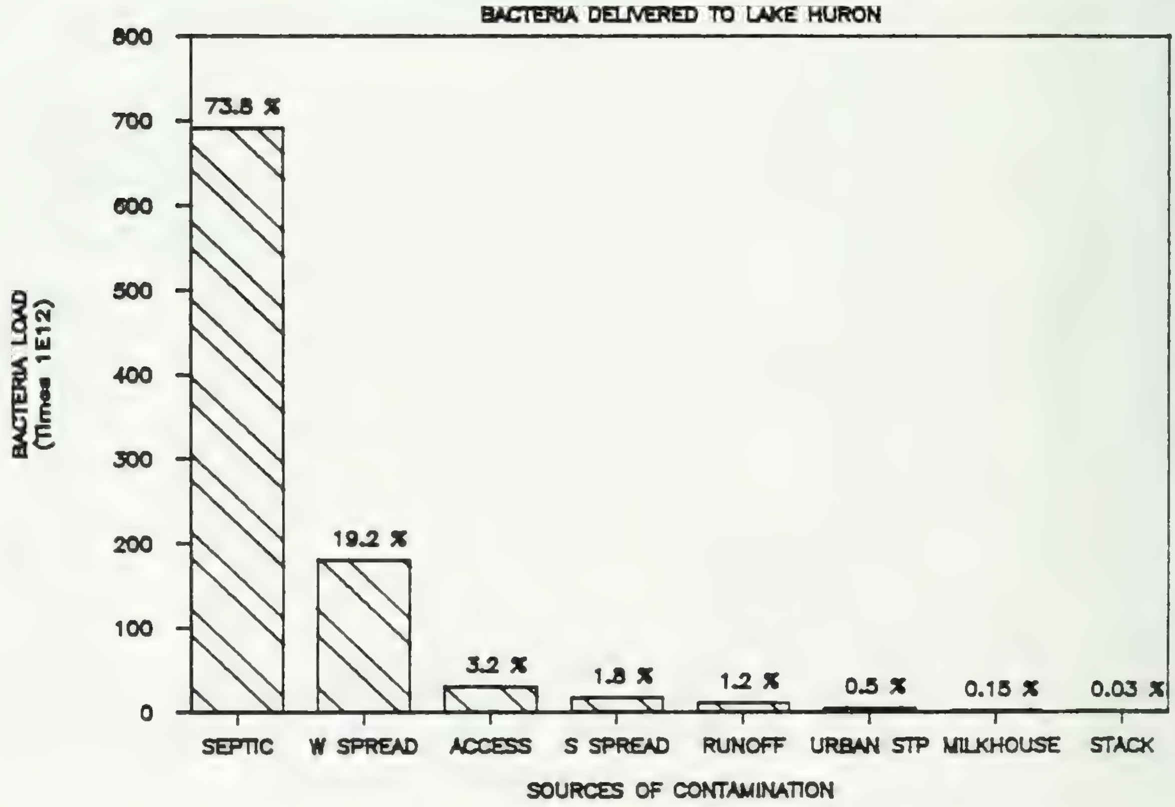


FIGURE 6 : LAKESHORE COTTAGES

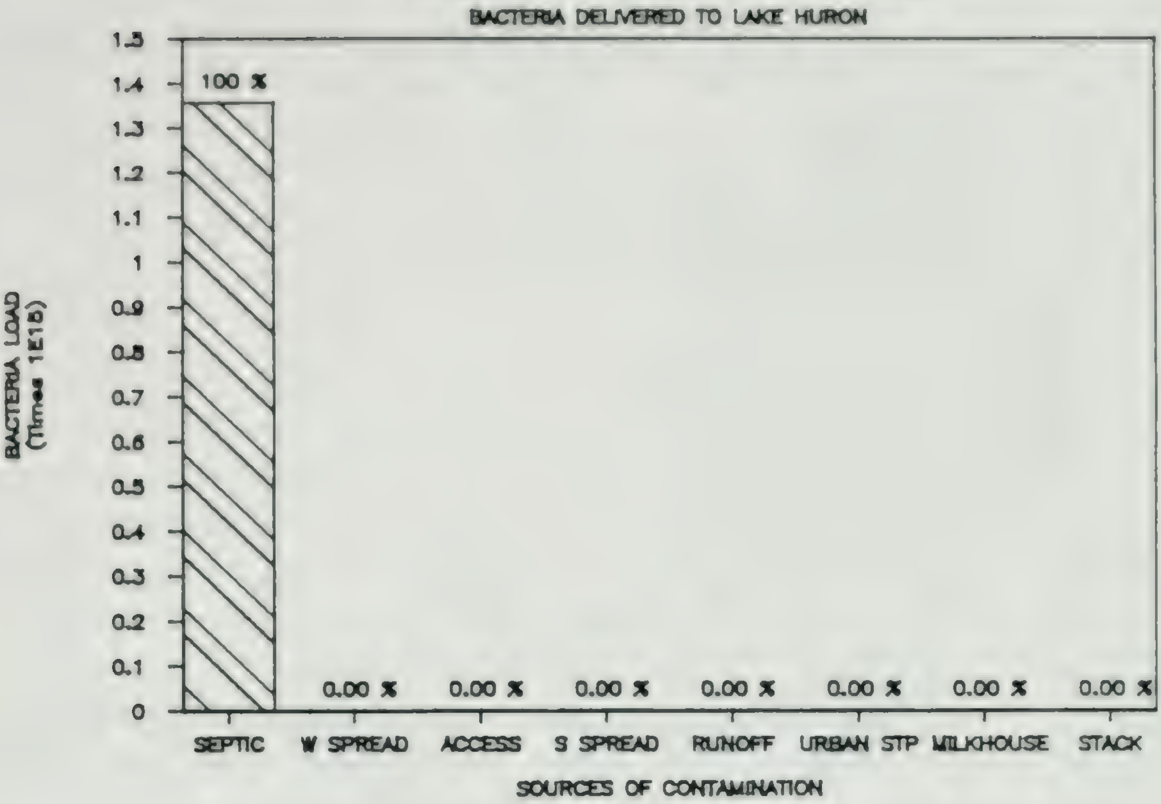


FIGURE 7 : AUSABLE RIVER WATERSHED

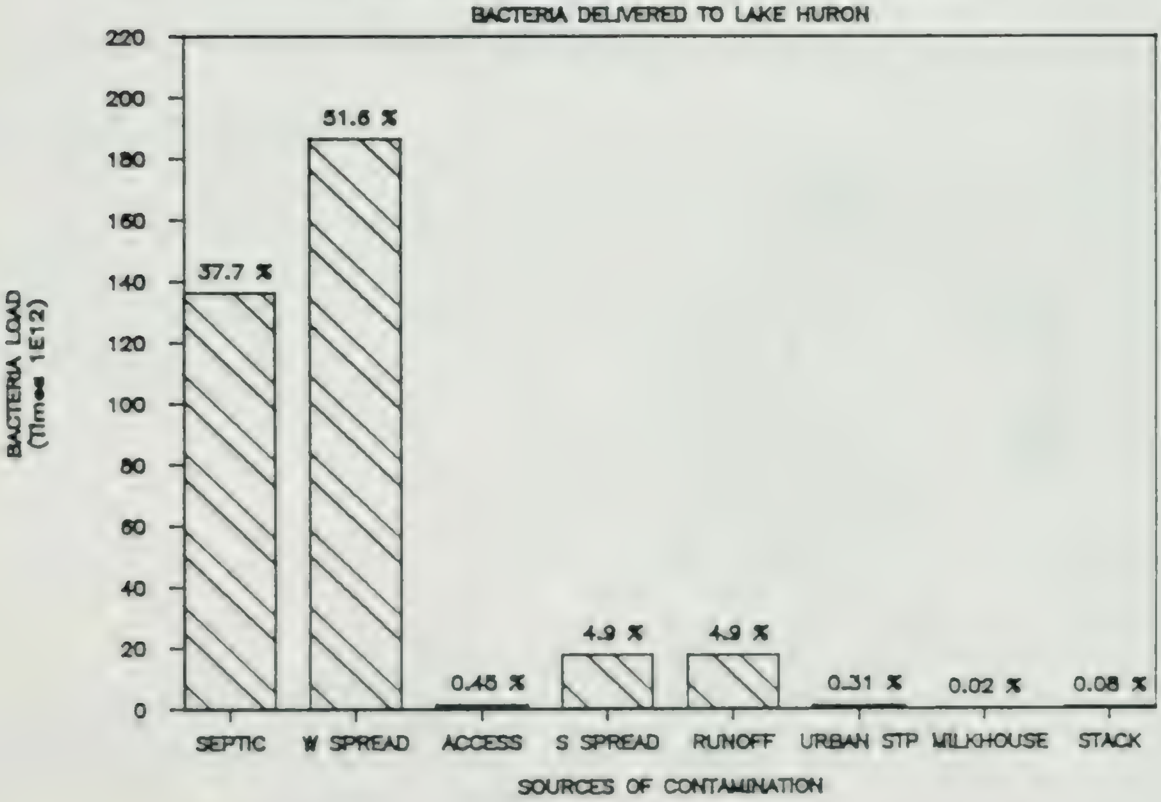


FIGURE 8 : PARKHILL CREEK WATERSHED

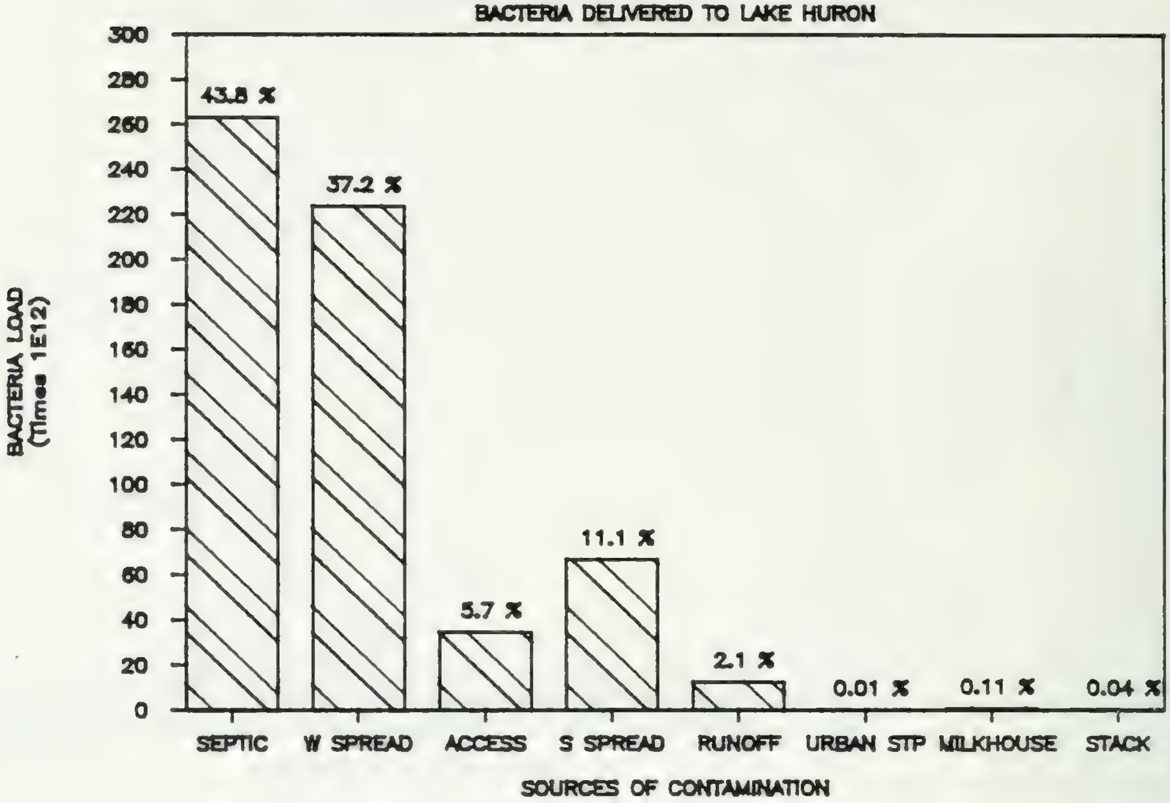
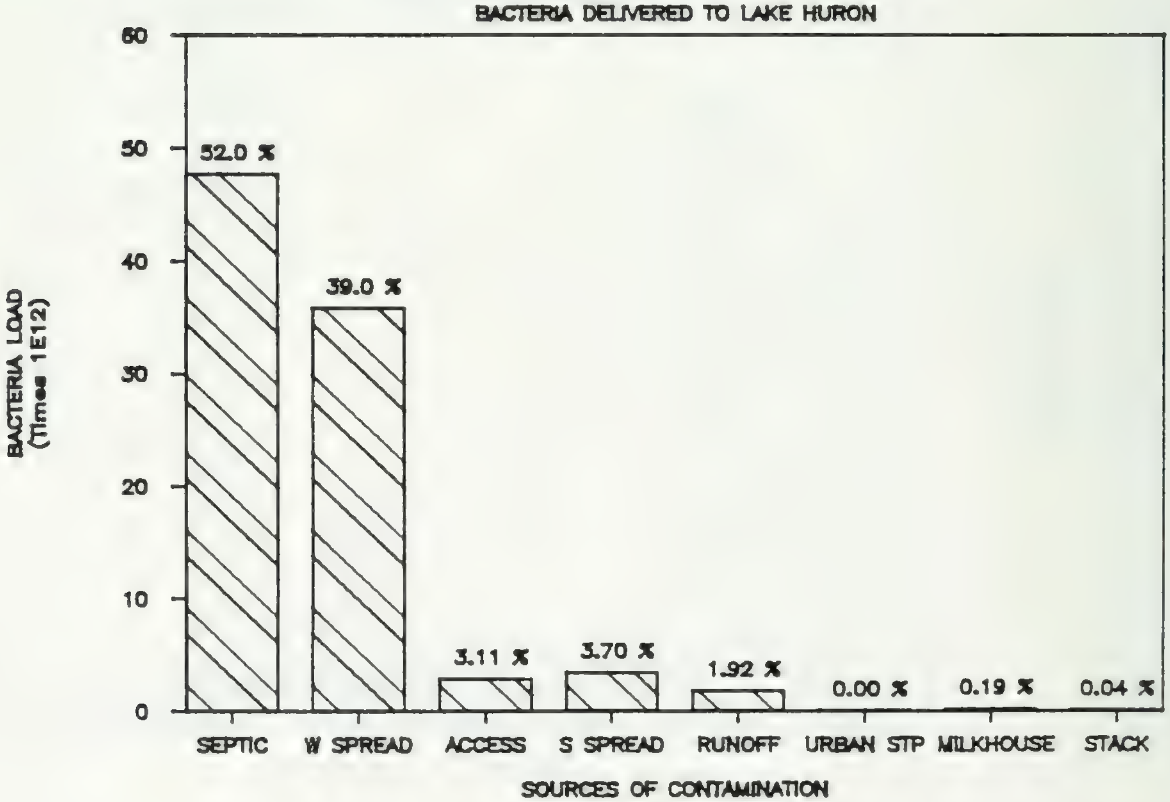


FIGURE 9 : MUD CREEK WATERSHED



Sediment deposits at jetties in Bayfield and Grand Bend are stable, indicating that in terms of sediment transport there may not be other significant local littoral drift subcells within the bounds of the A.B.C.A. C.U.R.B. Plan. Reinders (1988) recommends further detailed study of transport patterns and sediment supply analysis which may identify littoral drift subcells. Techniques measuring detailed lake bed sediment movement rates and patterns are still at an experimental stage (A. Scott, A.B.C.A. personal communication, 1989).

Grand Bend beach is expected to be impacted primarily by Parkhill Creek discharge. Lakeshore cottages and Lake Huron gullies may also contribute significant amounts of contamination to Lake Huron which can be reasonably expected to impact Grand Bend beaches on occasion. Without more detailed sediment transport information, C.U.R.B. Plan strategies must be applied to these areas as well as near-beach sub-watersheds in Parkhill Creek.

Figure 3 indicates that domestic septic systems may contribute 77.5 percent of the delivered bacteria load at Lake Huron. Contaminanted runoff from winter and summer spread manures contribute 18.6 percent of delivered bacteria loads. Livestock access sites contribute 2.7 percent. The remaining 1.2 percent is composed of farmyard and manure stack runoff, milkhouse waste and urban sewage treatment facilities. This trend is typical of delivered loads in all A.B.C.A. watersheds.

3.2. Phosphorous Loadings

The C.U.R.B. model permits phosphorous loadings from livestock operations, faulty septic systems and sewage treatment plants to be estimated. The results for each watershed are shown in Table 5 below. The total estimated load is 38.5 tonnes of which 70 percent is estimated to come from continuous discharge sources and 30 percent from pulse discharge sources.

FIGURE 10 : TOTAL PHOSPHORUS LOADING

BY SOURCE FOR ALL ABCA WATERSHEDS

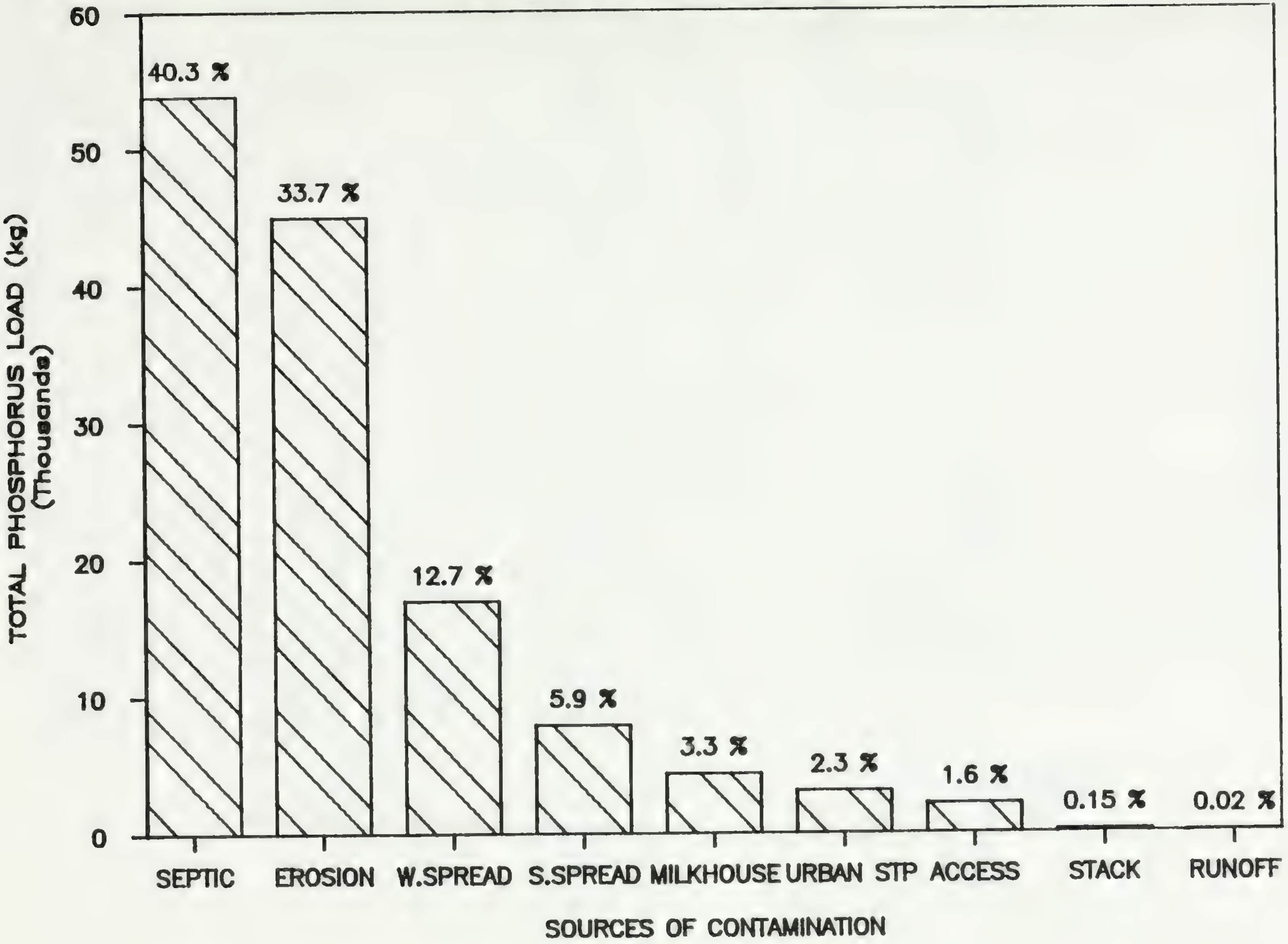


TABLE 5: Total Phosphorous Loads from Sewage Treatment Plants and Rural Sources in A.B.C.A. Watersheds

Watershed	Continuous P (kg)	Pulse P (kg)	Total P Load (kg)
Ausable River	26,922	11,014	37,936
Bayfield River	12,849	3,592	16,441
Parkhill Creek	8,792	7,889	16,681
Mud Creek	1,050	672	1,722
Gullies	6,570	1,904	8,474
Lakeshore (cottages)	4,180	0	4,180
Sewage Treatment Plants	1,932	1,155	3,087
TOTAL	62,295	26,226	88,521

Note: Rural Sources Only

In addition to the sources of phosphorous listed above erosion from croplands (which comprise 80 percent of the A.B.C.A. land area) contributes an estimated additional 45 metric tons of phosphorous. The phosphorous lost by erosion is calculated by multiplying the cropped land area (80 percent) by 0.22 kg P/ha/yr. The phosphorus loss due to erosion was derived from O.M.A.F. Publication 296, p.35, 1988. Combined with 88.5 tonnes of phosphorous contributed from livestock operation runoff, faulty septic systems and sewage treatment plants, the total amount of phosphorous contributed by the A.B.C.A. watersheds in a year is estimated to be 133.5 tonnes. This compares well on a unit area basis with the International Joint Commission (I.J.C.) estimated load of 3,000 tonnes of phosphorous entering Lake Huron per year from unspecified sources (I.J.C. 1988, p. 62).

Soil erosion accounts for 33.7 percent of all total phosphorus delivered to watercourses, more than all remaining sources combined. This suggests that a significant portion of the phosphorus load abatement can be shared by the whole rural farm community, not just livestock farm operators.

Figure 10 illustrates individual source phosphorous loads for the entire A.B.C.A. watershed. Soil erosion plus winter and summer spread manures accounts for 52.3 percent of the phosphorous delivered to the A.B.C.A. watercourses. At 40.3 percent, domestic septic systems are potentially the single largest source of phosphorous added to A.B.C.A. watercourses, as they are for bacteria loads delivered to Lake Huron.

Fifty percent of the cropland in the A.B.C.A. watershed is in grain corn, silage corn and soybeans. This accounts for 977 km^2 or 40 percent of the land area of the A.B.C.A. watershed. By comparing "C" factors in the Universal Soil Loss Equation (U.S.L.E.) for different tillage practices (Mohr 1988, p. 56), it is possible to estimate reductions in phosphorous losses when fall moldboard plowing is changed to chisel plowing or to no-till practices. Table 6 shows the changes in phosphorous loss for the various tillage practices for grain corn, silage corn and soybeans.

TABLE 6: Phosphorous Losses for Various Tillage Practices on Grain Corn, Silage Corn and Soybeans

Crop Type	"C" Factor	Phosphorous Loss (kg)	Percent Reduction in P Loss as Compared to mpf
Grain Corn (mpf)	0.38	13,961	-
Grain Corn (ch/cf)	0.25	9,214	34
Grain Corn (none)	0.06	2,094	85
Silage Corn (mpf)	0.53	2,553	-
Silage Corn (ch/cf)	0.40	1,915	25
Silage Corn (none)	0.13	638	75
Soybeans (mpf)	0.47	6,165	-
Soybeans (ch/cf)	0.43	5,610	9
Soybeans (none)	0.11	1,418	77

mpf- moldboard plow in fall
ch/cf - chisel plow in fall
none - no till

(Mohr 1988, p. 56)

3.3 Remedial Cost Analysis

Capital costs to reduce contamination of the A.B.C.A.'s watercourses have been estimated using suggested on-farm remedial costs indicated in Appendix 4. Tables 7 and 8 summarize predicted total capital costs for each major watershed area and by source of contamination respectively.

The total capital cost to reduce rural contamination sources by 100 percent is estimated to range from $24.5 million to $41.3 million dollars (Table 7). Subtracting lakeshore cottages (non-farm) costs reduces the range to $22.6 million dollars to $39.5 million dollars. The average cost for each of the 826 potentially contaminating livestock operations in the A.B.C.A. watershed would range from $16,000 to $37,000 dollars (including septic system) per farm. Total remedial construction costs on 5 livestock operations (described in the 1987 and 1988 A.B.C.A. Target Sub-basin Study Reports) has ranged from $26,000 to $72,000 dollars, averaging $47,000 dollars per farm.

Table 8 indicates maximum and minimum capital costs to eliminate contaminant sources estimated by the A.B.C.A. C.U.R.B. model. Faulty septic systems (which contribute 77.5 percent of estimated bacteria load delivered to Lake Huron) could be replaced for $13.1 million dollars. Manure stack runoff could be contained at a cost of between $7.5 million and $18.1 million dollars but there would be only 0.02 percent reduction in delivered bacteria load. Livestock access may be eliminated for $2.5 million to $6.6 million dollars and remove 2.7 percent of the bacteria load delivered to Lake Huron. Targetting lakeshore cottages and Gullies watersheds for comprehensive remedial work would reduce delivered bacteria load to Lake Huron by an estimated 69.0 percent (derived from Figure 2). The estimated capital cost would range from $4.1 million to $5.5 million dollars. Addressing all contaminant sources in the entire Parkhill Creek watershed would incur capital costs of $3.9 million to $7.2 million dollars and remove 7.2 percent of delivered bacteria load.

Section 3.1 indicates targetting reaches of lakeshore where discharges may impact specific beaches such as Grand Bend is not possible at this time. Sub-watersheds near beach areas deliver more bacteria than headwater sub-watersheds due to less travel time required. Impact of travel time on delivered bacteria loads from continuous and pulse sources can be seen in Appendix 2. Calculations have been performed on representative sub-watersheds of the A.B.C.A. incorporating delivered load and least capital cost remedial values to estimate the most cost effective remedial measure. Table 9 illustrates these results. Note that a combined ranking scheme (bacteria and phosphorus loads together) has not been devised for this report.

The most cost efficient removal of bacteria delivered to Lake Huron appears in near-lake sub-watersheds. Septic repairs are usually either first or second most cost-effective repair for both bacteria and total phosphorus removal. Target Sub-basin Study experience indicates that improperly installed septic bed weeping tiles in new septic systems may still contaminate nearby field drain tiles with bacteria and likely soluble phosphorus at the same time. Also, contaminated field tiles may require at least two months to "purge" and run clean, indicating a potential lag-time before improvements could be seen.

Feedlot remedial work appears to be reasonably cost effective for bacteria, but not phosphorus loads. In terms of overall bacteria loads, however, feedlot runoff contributes an estimated 1.06 percent of the annual delivered load (Figure 3). Remedial work on feedlots would probably not make an appreciable reduction in annual contaminant loads. Remedial work on livestock access sites would prove modestly cost-effective.

TABLE 7: Estimated Capital Costs to Reduce Bacterial Contamination Discharged to Lake Huron from Rural Watersheds of the A.B.C.A.

Watershed		Maximum Capital Cost	Minimum Capital Cost
Ausable River		$20,099,872	$11,302,047
Bayfield River		7,504,208	4,586,607
Parkhill Creek		7,235,878	3,942,230
Gullies		3,606,048	2,259,080
Lakeshore (cottages)		1,868,400	1,868,400
Mud Creek		1,017,864	522,349
	Total	$41,332,270	$24,480,713

TABLE 8: Estimated Capital Costs to Eliminate Bacterial Contamination by Source for the A.B.C.A.

Source		Maximum Capital Cost	Minimum Capital Cost
Milkhouse Waste		$ 726,000	$ 363,000
Livestock Access		6,640,000	2,490,000
Feedlot Runoff		2,795,520	1,024,240
Manure Stack Runoff		18,110,750	7,543,473
Rural Septic Systems		13,060,000	13,060,000
	Total	$41,332,270	$24,480,713

If more manure storage time can be gained when remedial runoff facilities are installed, additional benefits will be realized in the day to day livestock farm operation. As storage capacity increases, so does flexibility in manure spreading operations. Timing and rate of manure application can be more readily tailored to existing field conditions. This will reduce frequency of manure spreading under desperate (such as winter or wet) conditions that contribute to excessive manure application in any season. Related accidents causing manure spills will also be reduced, as well as crop nutrient loss. This is an important factor that must be considered as winter spread manure is often one of the largest sources of bacteria delivered to Lake Huron.

Septic systems and livestock access are generally less expensive to repair than to contain manure stack runoff and appear to give the greatest benefit. A.B.C.A. Target Sub-basin Study experience indicates that faulty septic systems are difficult to find and prove farmers are generally reluctant to restrict livestock access as they are unaware of the cumulative impacts visited upon receiving waters. Incentives in the form of grants, information, education and training are required to promote adoption of best management practices including regular maintenance of septic systems and stream fencing. These will incur costs in addition to those estimated by C.U.R.B. algorithms.

Phosphorus cost analysis yields indentical rank order in each of the sub-watersheds analyzed (Table 9).

The same repair costs were used and the most efficient reduction in phosphorus loads are in order:

1) milkhouse waste
2) septic systems
3) livestock access
4) feedlot runoff
5) manure stack runoff

(Note: Phosphorus contributed by soil erosion not included in above ranking analysis).

As base farm survey information is updated, these ratios may be subject to change.

Repair or remedial work to reduce bacteria contamination will simultaneously reduce related phosphorous loadings. To date, excessive growth in A.B.C.A. watersheds has not caused closure of any beaches to public recreation. Contamination by native soil-bound bacteria that is washed into watercourses is not addressed by C.U.R.B.

TABLE 9: Cost Analysis: Bacteria and Phosphorus Removed per Remedial Dollar in Selected A.B.C.A. Sub-watersheds

	BACTERIA					TOTAL PHOSPHORUS				
Watershed	Milkhouse	Access	Feedlot	Stack	Septic	Milkhouse	Access	Feedlot	Stack	Septic
Ausable										
A1	8	29	7.45×10^{6}	1.62×10^{4}	1.48×10^{2}	9.22×10^{-3}	3.88×10^{-4}	3.29×10^{-5}	2.98×10^{-5}	4.47×10^{-3}
A28	4.40×10^{6}	1.31×10^{7}	7.59×10^{7}	2.13×10^{5}	3.34×10^{7}	2.12×10^{-2}	7.70×10^{-4}	3.64×10^{-5}	3.04×10^{-5}	4.47×10^{-3}
Bayfield										
B1	4.88×10^{5}	9.48×10^{5}	2.35×10^{7}	6.57×10^{4}	5.71×10^{6}	1.38×10^{-2}	3.25×10^{-4}	1.86×10^{-5}	1.56×10^{-5}	4.47×10^{-3}
B11	2.71×10^{7}	2.11×10^{8}	1.67×10^{8}	5.74×10^{5}	4.12×10^{8}	1.06×10^{-2}	1.00×10^{-3}	3.19×10^{-5}	2.67×10^{-5}	4.47×10^{-3}
Parkhill										
P1	2.74×10^{5}	1.66×10^{6}	5.43×10^{7}	1.02×10^{5}	3.47×10^{6}	1.27×10^{-2}	9.35×10^{-4}	2.98×10^{-5}	2.49×10^{-5}	4.47×10^{-3}
P11	1.82×10^{7}	5.46×10^{8}	2.04×10^{8}	5.36×10^{5}	6.16×10^{8}	4.76×10^{-3}	1.74×10^{-3}	6.52×10^{-5}	5.45×10^{-5}	4.47×10^{-3}
Gullies	8.11×10^{7}	2.97×10^{8}	9.53×10^{7}	1.78×10^{5}	8.74×10^{8}	1.49×10^{-2}	6.64×10^{-4}	2.11×10^{-5}	1.77×10^{-5}	4.47×10^{-3}
Lakeshore	NA	NA	NA	NA	7.26×10^{8}	NA	NA	NA	NA	2.24×10^{-3}

NA: Not Applicable, no potentially contaminating livestock farms algorithms. Switching tillage practices from moldboard plowing to no-till on A.B.C.A. grain corn, silage corn and soybean acreages may reduce A.B.C.A. phosphorous loadings by 18.5 metric tons per year, slightly more than estimated phosphorous contributions by winter spread manures (Figure 10). Switching to no-till practices incurs minimal costs that are soon compensated by increased productivity (R. Trout, personal communication, 1989).

In order to determine what potential benefit may be credited to a specific course of remedial action, the impact of a watershed discharge plume on the beach in question must be evaluated. For inland swimming areas where the discharge plume has relatively immediate and wide spread impacts, this evaluation may be unnecessary. The removal of single or multiple contaminant sources will be more easily seen. In confined beaches it has not been possible to evaluate sub-watershed discharge plumes in Lake Huron for this report. Wind, wave and nearshore current directions affect watershed discharge plumes. Dispersion of contaminants in these plumes is affected by temperature gradients, groundwater seepage and tributary flow rates (R. Griffiths, personal communication, 1989). The effect of discharge plumes is to increase contaminants in receiving bodies of water. The elimination of a single contaminant source (i.e. septic) from the discharge plume may not be sufficient to significantly reduce the frequency of beach closures. Changes in flow rate, tributary load and lake conditions may continue to cause beach closures in spite of real reductions in contaminant load delivered to the lakes and in the tributary watershed.

Fecal bacteria concentrations in creeks and rivers increase substantially during rainfall and runoff conditions, dramatically increasing the bacteria load to Lake Huron (O.M.E. 1984, page 2, O.M.E. 1985, page 5). The A.B.C.A. C.U.R.B. model can be used to estimate summer rain event generated bacteria loads delivered to Lake Huron. C.U.R.B. strategies may be devised to reduce event-related contaminant loadings that cause beach closures during peak-use periods. Initial expectations were that these strategies may not be similar to strategies developed to reduce annual contaminant loadings.

Table 10 depicts A.B.C.A. C.U.R.B. model estimated rain event loads from three sub-watersheds of Parkhill Creek. Rain event related continuous discharge sources' loadings were calculated using high flow travel times and dividing the delivered load by the days of discharge per year. This estimated hypothetical delivered loadings for a rain event. Faulty septic systems and milkhouse waste delivered loads were divided by 365 days and livestock access loads by 180 days. Pulse source delivered loadings were divided by 26 on the assumption that on average there is one rain event that generates runoff

TABLE 10: Summer Rain Event Bacteria Loads Delivered to Lake Huron from Selected Sub-Watersheds of Parkhill Creek

LOCATION	PERIOD	CONTAMINANT SOURCES						
		Milkhouse	Access	Lot Runoff	Stack Runoff	Summer Spreading	Septic	Total
	Annual	4.10 E 9	2.29 E 11	3.08 E 12	4.32 E 10	3.16 E 12	1.70 E 12	
P1	Rain Event Day	1.65 E 9	1.86×10^{11}	1.18 E 1	1.66 E 9	1.76 E 11	6.82 E 11	1.17 E 12
	Percent of Total	0.14	15.98	10.16	0.14	15.09	58.29	100
	Annual	1.64 E 11	2.29 E 13	2.98 E 12	5.85 E 10	2.83 E 13	4.66 E 13	
P11	Rain Event Day	9.12 E 8	2.59 E 11	1.15 E 11	2.25 E 9	1.57 E 11	2.59 E 11	7.93 E 11
	Percent of Total	0.11	32.65	14.48	0.28	19.80	32.68	100
	Annual	0	6.15 E 11	1.68 E 11	3.67 E 9	5.21 E 11	5.49 E 13	
P13	Rain Event Day	0	1.46 E 10	6.47 E 9	1.41 E 8	2.90 E 10	6.43 E 11	6.93 E 11
	Percent of Total	0	2.10	0.93	0.02	4.18	92.76	100

NOTE: 1 E 10 equals 1 x 10^{10}

every two weeks. Summer spread manure delivered loads were divided by 18, assuming twice monthly rain events through spring, summer and fall. Winter-spread manure loads were not included in this analysis.

There is some variation in the rank-order of contaminant sources in the three sub-watersheds, but that is primarily due to location and numbers of contaminant sources. The three major contributors of bacteria to beaches on a rain event day are faulty septic systems, summer-spread manure and livestock access. Therefore, remedial strategies designed to reduce annual loads from these sources should also be effective reducing beach closures from summer rain events as well.

4.0 CONCLUSIONS

The nature of watercourse contamination in the A.B.C.A. watersheds can be drawn from this modelling exercise. The one of the largest potential source of contamination appears to be from faulty domestic septic systems for both fecal coliform bacteria and phosphorus. Other major sources include winter and summer spread manure as well as livestock access to watercourses. Soil erosion may contribute up to 45 tonnes of phosphorus to watercourses, second only to an estimated 54 tonnes from faulty septic discharges. The bacteria load contributed to watercourses by soil erosion is not addressed by the C.U.R.B. algorithms.

Tributary flow characteristics (specifically event and low flow travel times) have a dramatic effect on bacteria load delivered to Lake Huron. Lake Huron beaches in the A.B.C.A. area of jurisdiction are affected more by Lake Huron Gullies watersheds than larger tributary systems such as the Ausable River as shown in Figure 1.

Bacteria concentrations in watershed discharge plumes are affected by lake surface conditions. This affects frequency of beach closures. Frequency of beach closures due to local lake conditions is a factor that is not within the scope of this study. This factor alone may prohibit apparent success of a partially implemented contamination abatement strategy.

Cost analysis indicates that bacteria removed per remedial dollar spent varies from watershed to watershed when calculated in terms of bacteria delivered to Lake Huron. Most effective remedial work for reducing bacteria loads to beaches occurs near Lake Huron. Repair of domestic septic systems will yield cost effective reductions in phosphorus and bacteria, especially in shoreline watersheds.

At present, there are departures from suggested values suggested at the Kempenfelt Workshop. In particular, the A.B.C.A. T.S.S. indicates 60 percent of domestic septic systems may be faulty and that 340 litres per day may be a more realistic volume of domestic water usage. These two values alone quadruple Kempenfelt estimated loadings for both bacteria and phosphorus from domestic septic systems.

Low flow travel time has been evaluated in only 1 of 63 sub-watersheds, leaving considerable potential for revising individual sub-watershed delivered bacteria load as more tributary flow information is gathered.

At present, A.B.C.A. C.U.R.B. model results can only be considered a first approximation of the relative distribution of contaminant loads delivered to Lake Huron. Caution should be used if loads predicted within this report are used for other purposes.

5.0 C.U.R.B. RECOMMENDATIONS

1. **The number of faulty domestic septic systems should be reduced.**
   All rural (non-urban) septic systems should be inspected and certified environmentally sound by local Health Unit or appointed public agency. Certification period should be two years and dependent upon documented evidence that prescribed maintenance has been performed. Priority should be given to seasonal dwellings near beach areas since C.U.R.B. algorithms indicate the highest rate of contaminant delivery is from faulty septic systems on lakeshore properties and in near lake sub-watersheds.

2. **Winter spreading and excessive manure spreading in other seasons should be prohibited.**
   This is a major contributor of bacteria and phosphorus contamination to Lake Huron beaches from livestock operations. Contamination can be eliminated by revising the Agricultural Code of Practice to prohibit manure spreading on snow-covered and frozen ground.

3. **All handlers of animal waste should be trained and licensed by the Ontario Ministry of the Environment.**
   Joint O.M.E. and O.M.A.F. training sessions will ensure safe handling practices and increase awareness of potential contamination hazards.

4. **Livestock access to watercourses should be eliminated.**
   Providing alternate watering sources and loafing areas will reduce local bacteria-related health hazards and protect stream banks from accelerated erosion that increases suspended sediment and phosphorus loadings in watercourses. Municipalities should adopt by-laws that will protect municipal drains from physical damage by livestock.

5. **Financial incentives to encourage best manure management and environmentally sound domestic waste facilities must be offered.**
   The A.B.C.A. Target Sub-basin experienced full farm participation at 90 percent grant rate for remedial construction. Manure Management Awareness Program

farm surveys indicated a 50 percent grant rate was desirable for farm assistance programs. Therefore, grant rates should be increased beyond the historic 40 percent limit. At present, there are no effective and continuing agricultural waste management programs.

Grants must be conditional upon maintenance of remedial structures and permanent adoption of best management practices. Regulations should be developed and enforced following a 5 - 10 year grant period to prevent lax waste management attitudes developing following the incentive period.

Since municipalities will benefit from reduced damage to municipal drains and improved water quality locally, cost sharing with the Province should be considered for remedial structures and facilities.

6. **Lead and implementing agencies should be designated and their roles defined.**

Conservation Authorities are locally responsible agencies with a positive public profile with existing priorities in water quality protection. Being based upon watershed management units makes Conservation Authorities well equipped for the implementation of watershed contamination abatement strategies. The Ontario Ministry of the Environment should continue to fund Beaches programs to continue providing technical assistance to watershed residents on water quality issues as well as assisting local Health Units and Ministry Abatement and Technical Support staff with investigations of water quality impairment. Two full time positions are recommended for the A.B.C.A. for the next 5 years. Laboratory services should continue to be provided to support investigations of apparent contaminant sources and to assist surveillance of near beach drains.

Priority assistance should initially be given to residents and farm operators with high risk of contributing to contamination in near-beach sub-watersheds.

6.0 REFERENCES AND LITERATURE CITED

Agriculture Statistics for Ontario, 1986. Publication 20, Statistical Services Unit, Economics and Co-ordination Branch.

Ausable Bayfield Conservation Authority. "Socio-economic Characteristics of the Ausable Bayfield Watershed". Watershed Planning Technical Report # 11. Exeter, Ontario, 1983.

Balint, D., March 1983. Potential Farm Pollution From Manure Storage and Handling Systems in Watersheds of the A.B.C.A.

Balint, D., February 1984. Analysis of the Manure Management - Water Quality Program of the A.B.C.A.

Crabe, T., June 6, 1989. M.N.R., personal communication.

Dickinson, T., 1987. "Sediment Transport in Ontario Streams - How Much? When? How Often? From Where?" Canadian Water Resources Association. Managing Ontario Streams Seminar, Black Creek Pioneer Village, March 1987.

M. M. Dillon Limited, January 1975. Hydrology Report for Ausable Bayfield Conservation Authority.

Dollery, J., May 25, 1989. Bayfield Business Improvement Association, personal communciation.

Ecologistics Limited, 1988. PLOP (Pollution for Livestock Operations Predictor) A Planning Tool to Evaluate the Pollution Potential of Livestock Operations in Southern Ontario.

Farrell, R., January 5, 1989. Environment Officer, O.M.E. Owen Sound, personal communication.

Fuller, R., March 16, 1989. M.V.C.A., personal communication.

Graham, P., June 8, 1989. Township of Bayfield, personal communication.

Great Lakes Water Quality Agreement of 1978, January 1988. International Joint Commission United States and Canada.

Griffiths, R., 1989. O.M.E. London, personal communication.

Hocking, D., October 1988. Rural Beaches Strategy Program - Ausable Bayfield Conservation Authority - Target Sub-basin Study Report.

Hutt, C., January 5, 1989. O.M.E. Sarnia, personal communication.

Josephson, D.V.M., June 8, 1989. Centralia College V.L.S. Department, personal communication.

Kress, M. and G. Gifford, February 1984. "Fecal Coliform Release from Cattle Fecal Deposits", Water Resources Bulletin, American Water Resources Association.

Kutas, W., December 12, 1988. Senior Microbiological Technician, O.M.E. London, personal communication.

Lingard, S., June 9, 1989. Ontario Hydro, Grand Bend, personal communication.

McKinnon, J., 1988. Huron County Health Unit, personal communication.

Ministry of Agriculture and Food, 1988. 1988 Field Crop Recommendations, Publication 296.

Ministry of the Environment, 1984. Lake Huron Beaches: Factors Affecting Microbiological Water Quality in 1984 Summary Report. Ministry of the Environment, Southwestern Region, Technical Support.

Ministry of the Environment, 1985. Lake Huron Beach Study. A Microbiological Water Quality Evaluation of Grand Bend Beach and Related Pollution Sources in 1985. Ministry of the Environment, Southwestern Region, Technical Support.

Mohr, P., 1988. "Assessment of a Method of Monitoring Phosphorous Reduction from Cropland".

Palmateer, G., Microbiologist, O.M.E. London, personal communication.

Reinders and Associates Canada Limited, 1988. "Littoral Cell Definition and Sediment Budget for Ontario's Great Lakes" Brampton, Ontario.

Schilthuis, B., D.V.M., November 1985. "Water Testing and Water Quality".

Schilthuis, B., D.V.M., June 1984. "Goderich Veterninary Clinic Newsletter".

Scott, A., May 17, 1989. Water Resources Manager, A.B.C.A., Exeter, personal communication.

Sheppard, D., May 25, 1989. Grand Bend Chamber of Commerce, personal communication.

Stanford, E., D.V.M., June 8, 1989. Centralia College V.L.S. Department, personal communication.

The Village of Grand Bend and the County of Lambton. "Economic Development Opportunities in the Village of Grand Bend", 1983.

Thompson, D., February 10, 1989. Environmental Officer, O.M.E. London, personal communication.

Traut, R., April 19, 1989. Conservation Agronomist, Ausable Bayfield Conservation Authority personal communication.

Turnbull, R., December 7, 1988. O.M.E. London, personal communication.

Van Dreumel, D.V.M., June 14, 1989. Guelph University V.L.S. Department, personal communciation.

APPENDIX 1 : DELIVERED FECAL COLIFORM BACTERIA LOAD									
	BACTERIA DELIVERED TO BEACH BY SOURCE								
AUSABLE RIVER									
	MHW	ACCESS	RUNOFF	STACK	W SPREAD	S SPREAD	SEPTIC	URBAN STPs	% TOTAL
A1	1.52e+05	2.82e+06	3.14e+11	5.30e+09	3.70e+12	3.51e+11	6.26e+07		1.21
A2	1.21e+09	7.44e+10	3.19e+11	6.97e+09	4.84e+12	4.59e+11	6.05e+11	5.38e+05	1.75
A3	8.73e+04	6.52e+06	2.06e+11	4.05e+09	2.35e+12	2.23e+11	8.52e+07	7.96e+08	0.77
A4	0.00	0.00	0.00	0.00	0.00	0.00	3.26e+06		0.00
A5	3.68e+05	4.92e+06	8.59e+10	1.15e+09	2.95e+12	2.80e+11	1.22e+08		0.92
A6	2.46e+06	5.60e+07	1.28e+11	4.82e+09	3.42e+12	3.25e+11	1.35e+09	7.74e+05	1.08
A7	2.61e+06	2.05e+08	3.14e+11	7.26e+09	2.81e+12	2.67e+11	5.78e+08		0.94
A8	9.90e+06	5.99e+08	7.89e+11	1.47e+10	1.10e+13	1.04e+12	1.23e+09		3.56
A9	6.73e+05	8.15e+07	2.37e+11	5.35e+09	2.15e+12	2.04e+11	4.28e+08		0.72
A10	0.00	5.42e+07	8.26e+10	2.68e+09	6.91e+11	6.56e+10	5.01e+08		0.23
A11	7.12e+06	4.24e+08	5.20e+11	9.99e+09	5.73e+12	5.44e+11	2.44e+09	9.92e+11	2.16
A12	3.59e+07	5.22e+08	1.45e+11	4.13e+09	3.93e+12	3.73e+11	6.86e+09		1.24
A13	9.50e+06	1.39e+09	9.00e+11	1.42e+10	7.29e+12	6.91e+11	5.77e+09	3.14e+06	2.47
A14	1.36e+07	8.45e+08	7.10e+11	1.28e+10	5.56e+12	5.28e+11	1.87e+09		1.89

A15	0.00	2.80e+08	1.09e+11	3.79e+09	6.49e+11	6.15e+10	1.11e+09		0.23
A16	3.62e+07	2.78e+09	5.68e+11	1.16e+10	6.13e+12	5.81e+11	1.43e+10		2.02
A17	0.00	0.00	0.00	0.00	0.00	0.00	2.02e+09		0.00
A18	0.00	1.44e+09	1.72e+11	5.36e+09	2.02e+12	1.91e+11	1.53e+10		0.67
A19	1.42e+08	3.35e+09	3.82e+11	9.44e+09	7.02e+12	6.66e+11	3.47e+10		2.25
A20	3.46e+08	2.04e+10	9.55e+11	1.99e+10	9.89e+12	9.38e+11	5.78e+10		3.29
A21	4.27e+08	6.05e+09	1.97e+11	3.08e+09	6.84e+12	6.49e+11	5.31e+10		2.15
A22	6.57e+08	7.76e+10	1.95e+11	7.11e+09	3.99e+12	3.79e+11	1.43e+11		1.33
A23	1.24e+09	4.03e+10	3.01e+12	2.63e+10	1.44e+13	1.36e+12	2.55e+11		5.28
A24	0.00	2.02e+09	2.13e+10	7.37e+08	6.94e+11	6.59e+10	6.20e+10		0.23
A25	4.72e+09	1.54e+11	3.89e+12	5.00e+10	3.36e+13	3.19e+12	4.85e+11		11.46
A26	3.20e+09	1.54e+11	7.37e+11	1.83e+10	1.04e+13	9.88e+11	1.54e+12		3.84
A27	4.65e+09	1.64e+11	9.54e+11	2.14e+10	1.08e+13	1.02e+12	4.41e+12		4.80
A28	1.32e+10	6.31e+11	1.39e+12	2.90e+10	1.49e+13	1.41e+12	5.78e+12		6.68
A29	0.00	0.00	0.00	0.00	0.00	0.00	6.11e+12		1.69
A30	2.83e+10	2.85e+11	2.45e+11	4.69e+09	8.70e+12	8.25e+11	1.02e+13		5.61
A31	0.00	0.00	0.00	0.00	0.00	0.00	1.20e+13		3.32
A32	0.00	0.00	0.00	0.00	0.00	0.00	9.45e+13	1.13e+11	26.22
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
TOTAL	5.82e+10	1.62e+12	1.76e+13	3.04e+11	1.86e+14	1.77e+13	1.36e+14	1.11e+12	3.61e+14
%	0.02	0.45	4.87	0.08	51.64	4.90	37.74	0.31	100.00

APPENDIX 1 : DELIVERED FECAL COLIFORM BACTERIA LOAD

BAYFIELD RIVER

	MHW	ACCESS	RUNOFF	STACK	W SPREAD	S SPREAD	SEPTIC	URBAN STPs	% TOTAL
B1	2.93e+09	3.98e+10	4.30e+11	8.97e+09	1.13e+13	1.07e+12	1.84e+12		1.57
B2	2.89e+09	2.03e+11	8.95e+11	2.21e+10	9.57e+12	9.08e+11	9.76e+09		1.24
B3	1.07e+10	2.60e+11	6.03e+11	1.52e+10	1.18e+13	1.12e+12	4.98e+12		2.00
B4	2.44e+10	5.99e+11	7.11e+11	2.09e+10	1.36e+13	1.29e+12	6.22e+12	5.54e+11	2.45
B5	0.00	1.02e+12	2.76e+11	1.27e+10	5.32e+12	4.01e+11	1.33e+13		2.17
B6	3.25e+10	1.09e+12	4.30e+11	1.61e+10	7.86e+12	7.45e+11	7.26e+12		1.86
B7	1.34e+11	1.88e+12	9.97e+11	2.27e+10	2.21e+13	2.10e+12	2.95e+13		6.06
B8	3.77e+11	1.32e+13	2.88e+12	5.74e+10	2.37e+13	2.25e+12	1.34e+14	4.20e+12	19.32
B9	1.06e+11	2.32e+12	1.71e+12	3.20e+10	3.66e+13	3.47e+12	5.19e+13		10.27
B10	0.00	0.00	0.00	0.00	0.00	0.00	3.21e+13		3.43
B11	8.13e+10	5.05e+12	1.22e+12	3.13e+10	1.42e+13	1.34e+12	1.13e+14		14.45
B12	6.38e+11	4.54e+12	9.30e+11	1.06e+10	2.41e+13	2.29e+12	2.97e+14		35.17
	---------	---------	---------	---------	---------	---------	---------	---------	---------
TOTAL	1.41e+12	3.02e+13	1.11e+13	2.50e+11	1.80e+14	1.70e+13	6.92e+14	4.75e+12	9.36e+14
%	0.15	3.22	1.18	0.03	19.23	1.81	73.86	0.51	100.00

APPENDIX 1 : DELIVERED FECAL COLIFORM BACTERIA LOAD

PARKHILL CREEK

	MHW	ACCESS	RUNOFF	STACK	W SPREAD	S SPREAD	SEPTIC	URBAN STPs	% TOTAL
P1	4.10e+09	2.29e+11	3.08e+12	4.32e+10	3.34e+13	3.16e+12	1.70e+12		6.92
P2	1.95e+10	2.35e+11	1.23e+12	2.80e+10	1.31e+13	1.24e+12	1.84e+12		2.94
P3	0.00	1.61e+11	3.81e+11	1.23e+10	3.84e+12	3.64e+11	3.47e+12	1.04e+10	1.37
P4	3.28e+10	3.85e+11	9.48e+11	1.29e+10	5.99e+13	5.11e+13	4.02e+12		19.37
P5	0.00	2.27e+10	3.04e+11	8.61e+09	1.63e+12	1.55e+11	1.29e+12		0.57
P6	1.93e+10	2.51e+11	2.93e+11	5.11e+09	1.02e+13	9.67e+11	3.74e+12		2.57
P7	3.97e+10	5.05e+11	3.66e+11	6.19e+09	1.29e+13	1.22e+12	1.15e+13		4.41
P8	0.00	1.21e+12	5.95e+11	1.79e+10	7.80e+12	7.40e+11	3.12e+13		6.91
P9	1.63e+11	4.68e+12	1.57e+12	3.65e+10	2.45e+13	2.33e+12	3.29e+13		11.02
P10	0.00	2.18e+11	8.66e+10	2.57e+09	3.01e+12	2.85e+11	1.05e+13		2.35
P11	1.64e+11	2.29e+13	2.98e+12	5.85e+10	2.98e+13	2.83e+12	4.66e+13		17.52
P12	2.31e+11	2.93e+12	5.13e+11	8.51e+09	1.78e+13	1.69e+12	5.96e+13		13.77
P13	0.00	6.15e+11	1.68e+11	3.67e+09	5.49e+12	5.21e+11	5.49e+13	5.32e+10	10.28
	---------	---------	---------	---------	---------	---------	---------	---------	---------
TOTAL	6.73e+11	3.44e+13	1.25e+13	2.44e+11	2.23e+14	6.66e+13	2.63e+14	6.36e+10	6.01e+14
%	0.11	5.72	2.08	0.04	37.17	11.08	43.79	0.01	100.00

APPENDIX 1 : DELIVERED FECAL COLIFORM BACTERIA LOAD									
GULLIES									
	MHW	ACCESS	RUNOFF	STACK	W SPREAD	S SPREAD	SEPTIC	URBAN STPs	% TOTAL
Gn	2.76e+11	3.59e+12	4.66e+11	8.13e+09	1.62e+13	1.54e+12	2.85e+14		21.99
GULLIES	1.95e+12	5.34e+13	6.80e+12	9.46e+10	1.21e+14	1.15e+13	8.94e+14		78.01
	---------	---------	---------	---------	---------	---------	---------	---------	---------
TOTAL	2.22e+12	5.70e+13	7.26e+12	1.03e+11	1.37e+14	1.30e+13	1.18e+15	0.00	1.40e+15
%	0.16	4.08	0.52	0.01	9.84	0.93	84.45	0.00	100.00
LAKESHORE									
	MHW	ACCESS	RUNOFF	STACK	W SPREAD	S SPREAD	SEPTIC	URBAN STPs	% TOTAL
TOTAL	0.00	0.00	0.00	0.00	0.00	0.00	1.36e+15	0.00	100.00
	---------	---------	---------	---------	---------	---------	---------	---------	---------
%	0	0	0	0	0	0	100	0.00	100

APPENDIX 1 : DELIVERED FECAL COLIFORM BACTERIA LOAD

MUD CREEK									
	MHW	ACCESS	RUNOFF	STACK	W SPREAD	S SPREAD	SEPTIC	URBAN STPs	% TOTAL
M1	4.61e+10	1.06e+12	1.11e+12	2.60e+10	1.65e+13	1.57e+12	1.11e+13		34.33
M2	0.00	0.00	0.00	0.00	0.00	0.00	23599027862463		25.74
M3	1.27e+11	1.79e+12	6.44e+11	1.51e+10	1.93e+13	1.83e+12	12924227021275		39.93
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TOTAL	1.73e+11	2.85e+12	1.76e+12	4.12e+10	3.58e+13	3.39e+12	4.77e+13	0.00	9.17e+13
%	0.19	3.11	1.92	0.04	39.04	3.70	52.00	0.00	100.00

APPENDIX / PHOSPHORUS CONTAMINANT LOAD (KG)

AUSABLE	MILKHOUSE	ACCESS	RUNOFF	STACK	W. SPREAD	S. SPREAD	SEPTIC	URBAN STP	LOAD	% OF TOTAL
A1	165.96	37.28	1.38	9.76	591.03	177.31	1891.57		2874.29	7.27
A2	88.95	66.31	0.9	5.61	390.09	117.03	1231.53	330	2230.42	5.64
A3	63.53	57.75	0.67	4.15	350.32	105.09	1722.53	176	2480.04	6.27
A4	0	0	0	0	0	0	16.1		16.10	0.04
A5	88.95	14.45	0.2	1.23	362.3	108.69	821.02		1396.84	3.53
A6	112.96	31.21	0.34	4	314.77	94.43	1722.53	910	3190.24	8.07
A7	58.88	56.36	0.81	5.05	228.9	68.67	362.21		780.88	1.97
A8	110.93	81.59	0.92	5.75	499.43	149.83	382.34		1230.79	3.11
A9	43.77	64.5	0.63	3.92	209.99	63	772.72		1158.53	2.93
A10	0	36.6	0.22	1.35	65.83	19.75	772.72		896.47	2.27
A11	138.52	100.21	1.62	10.09	454.3	136.29	1320.07	119	2280.10	5.77
A12	105.2	8.84	0.31	0.67	229.52	68.86	660.04		1073.44	2.71
A13	82.59	146.73	1.62	7.96	502.01	150.6	1392.51	76	2360.02	5.97
A14	117.91	89.35	1.03	5.27	383.17	114.95	450.76		1162.44	2.94
A15	0	8.86	0.2	1.23	36.21	10.86	80.49		137.85	0.35
A16	69.89	65.22	0.86	5.38	324.56	97.37	764.68		1327.96	3.36
A17	0	0	0	0	0	0	88.54		88.54	0.22
A18	0	12.87	0.23	1.46	90.54	27.16	313.92		446.18	1.13
A19	69.89	20.1	0.66	3.14	293.62	88.09	474.9		950.40	2.40
A20	76.24	54.57	0.81	5.38	359.65	107.9	354.17		958.72	2.42
A21	69.89	12.04	0.13	0.78	235.95	70.78	241.48		631.05	1.60
A22	48.09	69.11	0.44	1.46	119.79	35.94	289.77		564.60	1.43
A23	95.45	37.84	0.88	5.49	435.06	130.52	547.35		1252.59	3.17
A24	0	0.81	0.02	0.11	18.11	5.43	56.34		80.82	0.20
A25	268.29	106.03	2.57	14.91	965.48	289.64	764.68		2411.60	6.10
A26	57.18	33.54	0.85	5.27	244.7	73.41	764.68		1179.63	2.98
A27	74.84	32.21	0.47	2.92	248.42	74.53	1972.06		2405.45	6.08
A28	63.53	36.96	0.67	4.15	277.81	83.34	772.72		1239.18	3.13
A29	0	0	0	0	0	0	257.57		257.57	0.65
A30	52.53	6.42	0.07	0.45	137.75	41.33	523.2		761.75	1.93
A31	0	0	0	0	0	0	716.38		716.38	1.81
A32	0	0	0	0	0	0	973.76	36	1009.76	2.55
TOTAL	2,123.97	1,287.76	19.51	116.94	8,369.31	2,510.80	23,475.34	1,647.00	39,550.63	100.00
% of Total	5.37	3.26	0.05	0.30	21.16	6.35	59.36	4.16	100.00	

APPENDIX I PHOSPHORUS CONTAMINANT LOAD

BAYFIELD	MILKHOUSE	ACCESS	RUNOFF	STACK	W. SPREAD	S. SPREAD	SEPTIC	URBAN STP	LOAD	% OF TOTAL
B1	82.59	13.65	0.34	2.13	286.56	85.97	1440.81		1912.05	10.95
B2	77.24	54.21	0.81	5.05	241.02	72.31	547.35		997.99	5.71
B3	57.18	16.9	0.29	1.79	224.17	67.25	740.53		1108.11	6.34
B4	66.08	19.68	0.65	2.8	229.29	68.97	466.85	320.00	1174.32	6.72
B5	0	15.37	0.22	1.35	78.57	18.72	458.81		573.04	3.28
B6	63.46	25.91	0.23	1.46	125.55	37.66	394.41		648.68	3.71
B7	90.65	15.48	0.76	4.71	293.96	88.19	555.40		1049.15	6.01
B8	132.61	56.43	0.86	4.26	281.47	84.44	1312.02		1872.09	10.72
B9	152.48	40.63	0.47	2.92	554.92	166.48	2076.48		2994.38	17.14
B10	0	0	0	0	0	0	1006.15		1006.15	5.76
B11	31.77	24.02	0.23	1.46	171.07	51.32	1231.53		1511.40	8.65
B12	111.56	9.64	0.16	1.01	253.43	76.03	1440.81	726.00	2618.64	14.99
TOTAL	865.62	291.92	5.02	28.94	2,740.01	817.34	11,671.15	1,046.00	17,466.00	100.00
% of Total	4.96	1.67	0.03	0.17	15.69	4.68	66.82	5.99	100.00	

PARKHILL	MILKHOUSE	ACCESS	RUNOFF	STACK	W. SPREAD	S. SPREAD	SEPTIC	URBAN STP	LOAD	% OF TOTAL
P1	190.60	129.09	1.69	10.54	925.01	277.50	2,189.39		3,723.82	21.73
P2	104.50	15.28	1.01	6.28	249.41	74.82	273.67		724.97	4.23
P3	0.00	10.47	0.22	1.35	72.43	21.73	515.15	174.00	795.35	4.64
P4	203.64	87.86	0.67	2.14	1,171.38	3,156.98	692.23		5,314.90	31.01
P5	0.00	0.81	0.20	1.23	27.98	8.39	104.64		143.25	0.84
P6	50.83	8.03	0.09	0.56	171.60	51.48	273.67		556.26	3.25
P7	57.18	8.84	0.11	0.67	195.51	58.65	458.81		779.77	4.55
P8	0.00	12.87	0.25	1.57	108.31	32.49	756.63		912.12	5.32
P9	100.40	35.03	0.49	3.03	320.63	96.19	563.45		1,119.22	6.53
P10	0.00	0.81	0.02	0.11	34.74	10.42	88.54		134.64	0.79
P11	42.81	72.91	0.95	5.94	335.45	100.64	338.07		896.77	5.23
P12	57.18	8.84	0.11	0.67	198.97	59.69	410.51		735.97	4.29
P13	0	4.81	0.05	0.34	72.43	21.73	982.00	220.00	1,301.36	7.59
TOTAL	807.14	395.65	5.86	34.43	3,883.85	3,970.71	7,646.76	394.00	17,138.40	100.00
% of Total	4.71	2.31	0.03	0.20	22.66	23.17	44.62	2.30	100.00	

APPENDIX / PHOSPHORUS CONTAMINANT LOAD

GULLIES	MILKHOUSE	ACCESS	RUNOFF	STACK	W. SPREAD	S. SPREAD	SEPTIC	URBAN STP	LOAD	% OF TOTAL
Gullies North	50.83	8.03	0.09	0.56	171.60	51.48	1456.91		1739.50	20.54
Gullies	358.49	119.54	1.51	9.42	1282.92	384.88	4571.95		6728.71	79.46
TOTAL	409.32	127.57	1.6	9.98	1454.52	436.36	6028.86	0	8468.21	100.00
% of Total	4.83	1.51	0.02	0.12	17.18	5.15	71.19	0.00	100.00	

SUMMARY

LAKESHORE	MILKHOUSE	ACCESS	RUNOFF	STACK	W. SPREAD	S. SPREAD	SEPTIC	URBAN STP	LOAD	% OF TOTAL
TOTAL	0.00	0.00	0.00	0.00	0.00	0.00	4177.54		4177.54	100.00
	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0	100.00	

SUMMARY

MUDCREEK										
M1	63.53	17.70	0.49	1.91	248.25	74.47	426.61		832.96	48.37
M2	0.00	0.00	0.00	0.00	0.00	0.00	120.74		120.74	7.01
M3	105.20	18.10	0.31	1.91	265.35	79.61	297.82		768.30	44.62
TOTAL	168.73	35.80	0.80	3.82	513.60	154.08	845.17	0.00E+00	1722.00	100.00
% of Total	9.80	2.08	0.05	0.22	29.83	8.95	49.08	0.00	100.00	

APPENDIX I

AUSABLE RIVER

	PHOSPHORUS (kg)		
SUB-WATERSHED	TCD TOTAL	PULSE TOTAL	GRAND TOTAL
A1	2,094.8	779.4	2,874.2
A2	1,390.0	514.0	1,904.0
A3	1,840.0	460.0	2,300.0
A4	16.1	0.0	16.1
A5	924.0	472.0	1,396.0
A6	1,870.0	414.0	2,284.0
A7	477.0	303.0	780.0
A8	575.0	656.0	1,231.0
A9	881.0	278.0	1,159.0
A10	809.0	87.1	896.1
A11	1,560.0	602.0	2,162.0
A12	806.0	299.0	1,105.0
A13	1,620.0	662.0	2,282.0
A14	658.0	504.0	1,162.0
A15	89.4	48.5	137.9
A16	900.0	428.0	1,328.0
A17	88.5	0.0	88.5
A18	327.0	119	446.0
A19	565.0	386.0	951.0
A20	485.0	474.0	959.0
A21	323.0	308.0	631.0
A22	407.0	158.0	565.0
A23	681.0	572.0	1,253.0
A24	57.2	23.7	80.9
A25	1,140.0	1,270.0	2,410.0
A26	855.0	324.0	1,179.0
A27	2,080.0	326.0	2,406.0
A28	873.0	366.0	1,239.0
A29	258.0	0.0	258.0
A30	582.0	180.0	762.0
A31	716.0	0.0	716.0
A32	974.0	0.0	974.0
	26,922.0	11,013.7	37,935.7

SEWAGE TREATMENT FACILITIES

	PHOSPHORUS (kg)		
	TCD TOTAL	PULSE TOTAL	TOTAL
EXETER	330.0		330.0
HENSALL		176.0	176.0
HURON PARK	910.0		910.0
LUCAN		119.0	119.0
AILSA CRAIG	76.0		76.0
THEDFORD		36.0	36.0
	1,316.0	331.0	1,647.0

APPENDIX I

PARKHILL CREEK

	PHOSPHORUS (kg)		
	TCD TOTAL	PULSE TOTAL	TOTAL
P1	2,510.0	1,210.0	3,720.0
P2	393.0	332.0	725.0
P3	526.0	95.7	621.7
P4	925.0	4,330.0	5,255.0
P5	105.0	37.8	142.8
P6	333.0	224.0	557.0
P7	525.0	255.0	780.0
P8	769.0	143.0	912.0
P9	699.0	420.0	1,119.0
P10	89.3	45.3	134.6
P11	454.0	443.0	897.0
P12	477	259	736.0
P13	987	94.5	1,081.5
	8,792.3	7,889.3	16,681.6

SEWAGE TREATMENT FACILITIES

	PHOSPHORUS (kg)		
	TCD TOTAL	PULSE TOTAL	TOTAL
PARKHILL	0.0	174.0	174.0
GRAND BEND	0.0	220.0	220.0
		394.0	394.0

APPENDIX I

BAYFIELD RIVER

PHOSPHORUS (kg)

	TCD TOTAL	PULSE TOTAL	TOTAL
B1	1,540.0	375.0	1,915.0
B2	691.0	319.0	1,010.0
B3	815.0	293.0	1,108.0
B4	553.0	302.0	855.0
B5	474.0	98.9	572.9
B6	484.0	165.0	649.0
B7	662.0	388.0	1,050.0
B8	1,500.0	371.0	1,871.0
B9	2,270.0	725.0	2,995.0
B10	1,010.0	0.0	1,010.0
B11	1,290.0	224.0	1,514.0
B12	1,560.0	331.0	1,891.0
	12,849.0	3,591.9	16,440.9

SEWAGE TREATMENT FACILITIES

PHOSPHORUS (kg)

	TCD TOTAL	PULSE TOTAL	TOTAL
SEAFORTH			
CLINTON	530.0		530.0
HURONVIEW		110.0	110.0
VANASTRA	86.0		86.0
	616.0	110.0	726.0

APPENDIX 1

MUD CREEK WATERSHED

	PHOSPHORUS (kg) TCD TOTAL	PULSE TOTAL	TOTAL
M1	508.0	325.0	833.0
M2	121.0	0.0	121.0
M3	421.0	347.0	768.0
	1,050.0	672.0	1,722.0

GULLIES

	PHOSPHORUS (kg) TCD TOTAL	PULSE TOTAL	TOTAL
GULLIES	5,050.0	1,680.0	6,730.0
Gn	1,520.0	224.0	1,744.0
	6,570.0	1,904.0	8,474.0

LAKESHORE

PHOSPHORUS (kg) TCD TOTAL	PULSE TOTAL	TOTAL
4,180.0	0.0	

APPENDIX 2
AUSABLE RIVER AND TRIBUTARIES

Sub-Watershed #	Area km^2	Longest Watercourse km	Elevation Difference m	Time of Concentration hr	Velocity km/hr	Time of Concentration For Centroid hr	Travel Time Centroid to Beach Low Flow Days	Travel Time Centroid to Beach High Flow Days
1	94.3	25.7	67.1	7.6	3.38	3.9	18.4	3.2
2	43.8	9.8	26.5	3.7	2.65	1.85	17.02	2.96
3	101.5	30.7	48.5	11.1	2.77	5.55	17.94	3.12
4	5.2	2.4	1.5	2.1	1.14	1.05	16.33	2.06
5	31.9	15.3	48.8	5.0	3.06	2.5	16.68	2.90
6	61.4	17.5	10.1	10.6	1.65	5.3	14.78	2.57
7	27.2	11.1	58.8	3.2	3.47	1.6	13.97	2.47
8	26.4	4.5	3.0	3.5	1.29	1.75	13.17	2.29
9	36.5	12.4	30.5	4.7	2.64	2.35	13.18	2.64
10	29.3	8.8	22.9	3.5	2.51	1.75	13.00	2.61
11	105.7	25.3	53.0	7.8	3.2	3.9	13.8	2.4
12	45.1	15.3	14.0	8.0	1.91	4.0	11.79	2.05
13	70.7	16.7	75.3	4.7	3.55	2.35	12.86	2.24
14	26.4	16.9	67.7	4.9	3.45	2.45	12.88	2.24
15	3.1	13.7	41.1	5.5	2.5	2.75	11.5	2.00
16	34.2	0.8	0.3	1.2	0.67	0.6	11.16	1.94
17	0.3	-	-	0.8	-	0.4	10.93	1.9
18	12.4	6.4	1.8	6.4	1.0	3.2	10.06	1.73
19	26.9	9.7	50.6	2.9	3.34	1.45	9.60	1.57
20	35.2	12.9	27.4	5.1	2.53	2.55	8.60	1.51
21	19.9	9.2	55.5	2.6	3.54	1.3	8.34	1.45
22	21.2	13.7	32.6	5.1	2.69	2.55	7.42	1.24
23	42.7	17.1	48.8	5.6	3.05	2.8	7.46	1.30
24	10.6	8.4	44.8	2.6	3.23	1.3	6.50	1.13
25	65.8	21.7	44.2	7.7	2.82	3.85	7.13	1.26
26	37.3	11.1	53.3	3.3	3.36	1.65	5.81	1.01
27	20.5	8.5	53.3	2.5	3.4	1.25	5.69	0.99
28	59.3	20.9	25.9	9.1	2.30	4.55	4.31	0.75
29	8.0	5.5	19.8	2.1	2.62	1.05	2.99	0.52
30	24.1	12.7	50.3	4.1	3.10	2.05	3.22	0.56
31	23.1	8.7	3.0	7.5	1.16	3.75	3.39	0.59
32	23.6	15.8	6.1	11.4	1.39	5.7	1.38	0.24
						Watershed Average	10.48	1.822

BAYFIELD RIVER AND TRIBUTARIES

Sub-Watershed #	Area km^2	Longest Watercourse km	Elevation Difference m	Time of Concentration hr	Velocity km/hr	Time of Concentration For Centroid hr	Travel Time Centroid to Beach Low Flow Days	Travel Time Centroid to Beach High Flow Days
1	29.0	10.5	19.8	4.5	2.3	2.25	6.33	1.1
2	33.9	7.1	12.2	3.4	2.1	1.7	6.27	1.09
3	38.3	16.7	6.7	11.8	1.4	5.9	4.43	0.77
4	24.1	14.5	34.4	5.3	2.7	2.65	3.65	0.635
5	11.4	5.6	27.7	2.0	2.8	1.0	2.76	0.48
6	35.2	13.2	27.7	5.2	2.5	2.6	3.28	0.57
7	20.7	11.6	37.2	3.8	3.1	1.9	2.07	0.36
8	70.2	20.8	77.4	2.4	8.7	1.2	1.32	0.23
9	107.5	33.8	96.6	9.5	3.6	4.75	2.93	0.51
10	47.9	14.5	14.9	7.3	2.0	3.65	2.65	0.46
11	48.7	11.4	68.3	3.1	3.7	1.55	1.44	0.25
12	38.3	14.5	54.9	4.4	3.3	2.2	0.52	0.09
						Watershed Average	**3.14**	**0.55**

Time of Concentration

- time for water to flow from most remote (in time of flow) point of the area to the outlet once soil all saturated.

PARKHILL CREEK AND TRIBUTARIES

Sub-Watershed #	Area km^2	Longest Watercourse km	Elevation Difference m	Time of Concentration hr	Velocity km/hr	Time of Concentration For Centroid hr	Travel Time Centroid to Beach Low Flow Days	Travel Time Centroid to Beach High Flow Days
1	139.6	42.6	61.9	15.1	2.8	7.55	6.9	1.2
2	14.8	9.5	41.5	3.0	3.2	1.5	4.43	0.77
3	12.95	6.3	26.2	2.3	2.7	1.15	4.37	0.76
4	69.7	12.9	42.7	4.3	3.0	2.15	4.6	0.80
5	8.8	3.7	14.6	1.5	2.5	0.75	3.74	0.65
6	37.0	14.0	48.2	4.5	3.1	2.25	3.62	0.63
7	29.0	9.0	28.7	3.3	2.7	1.65	2.93	0.51
8	34.2	7.4	22.9	2.9	2.6	1.45	2.36	0.41
9	30.8	12.1	47.2	3.8	3.2	1.9	1.94	0.34
10	7.0	1.9	9.4	0.9	2.1	0.45	1.15	0.2
11	22.8	12.7	49.4	4.0	3.2	2.0	0.98	0.17
12	31.3	9.4	36.6	3.2	2.9	1.6	0.92	0.16
13	30.8	20.5	4.6	17.0	1.2	8.5	2.01	0.35
						Watershed Average	3.07	0.53

MUD CREEK AND TRIBUTARIES

Sub-Watershed #	Area Km^2	Longest Watercourse Km	Elevation Difference m	Time of Concentration hr	Velocity Km/hr	Time of Concentration For Centroid hr	Travel Time Centroid to Beach	
							Low Flow Days	High Flow Days
1	-	19.3	5.0	17.0	1.2	8.5	2.9	0.5
2	-	10.6	30.0	33.0	2.7	1.65	0.6	0.1
3	-	37.0	46.0	11.1	2.77	5.55	2.3	0.4
						Watershed Average	1.93	0.33

GULLIES

Sub-Watershed #	Area km^2	Longest Watercourse km	Elevation Difference M	Time of Concentration Hrs.	Velocity Km/hr.	Time of Concentration For Controid Hrs.	Travel Time Controid to Beach	
							Low Flow Hrs.	High Flow Hrs.
-	-	11.7	7.6	3.1	3.7	1.55	0.6	0.1

APPENDIX 3: C.U.R.B. Algorithms

CONTINUOUS DISCHARGES

Milkhouse Wastes

$$\frac{\text{Concentration}}{\text{L}} \times \frac{\text{L}}{\text{day}} \times \begin{matrix}\text{N}\\ \text{cows}\end{matrix} \times \begin{matrix}\text{305 days}\\ \text{lactation}\end{matrix} \times \begin{matrix}\text{50000\%}\\ \text{tile growth}\end{matrix} \ \text{(bacteria only)}$$

Livestock Access

$$\frac{\text{Contaminant Load}}{\text{defecation}} \times \frac{\text{EAU}}{\text{access}} \times \begin{matrix}0.18\\ \text{probability}\\ \text{defecation}\end{matrix} \times \begin{matrix}2.5\\ \dfrac{\text{defecations}}{\text{day}}\end{matrix} \times \begin{matrix}1.6\\ \text{location}\\ \text{factor}\end{matrix} \times \begin{matrix}\text{N}\\ \text{animals}\\ \text{access}\end{matrix} \times \begin{matrix}180\\ \text{days}\end{matrix}$$

Septic Discharges

$$\frac{\text{Concentration}}{\text{L}} \times \frac{340.95\ \text{L}}{\text{day}} \times \text{N dwelling} \times 3.5\ \frac{\text{residents}}{\text{dwelling}} \times \begin{matrix}0.6\\ \text{failure}\end{matrix} \times \text{365 days}$$

PULSE DISCHARGES

Feedlot Runoff

$$\text{Runoff Load} = \frac{\text{Contaminant}}{\text{ha-mm}} \times \text{AMP} \times \text{Lot area (ha)} \times \underset{\text{rain}}{609\ (\text{mm})} \times \underset{\text{delivery}}{0.8}$$

Average Manure Accumulated (AMA)

$$\text{AMA} = \underset{\text{animals}}{\text{N}} \times \text{EAU} \times 1.31\ \frac{\text{kg}}{\text{hr}} \times 18\ \text{yard}\ \frac{\text{hr}}{\text{day}} \times \underset{\text{between scraping}}{7\ \text{days}} \ / 2$$

Average Manure Pack

$$\text{AMP} = \text{AMA / Lot area} \times \underset{\text{(kg per ha)}}{\frac{1}{67180}}$$

Manure Stack Runoff

$$\text{Runoff Load} = \frac{\text{Contaminant}}{\text{ha-mm}} \times \underset{\text{rain}}{914\ (\text{mm})} \times \underset{\text{percent runoff}}{0.67} \times \underset{\substack{\text{average}\\ \text{stack area}}}{\text{ASA (ha)}} \times \underset{\text{delivery}}{0.8}$$

$$\text{ASA} = 3.14 \times (0.577 \times (\text{ASV}/0.352)^{1/3})^{2/10,000}$$

$$\text{ASV} = \underset{\text{produced}}{\text{Volume of manure}} - \underset{\text{left in feedlot}}{\text{Volume of manure}} \times 1/(\text{number of cleanouts per year} + 1)$$

OR:

$$\text{ASV} = \frac{\text{(Volume of manure)}}{\text{day}} \times \underset{\text{animals}}{\text{N}} \times \underset{\text{days}}{365)} - \underset{\text{animals}}{(\text{N}} \times \underset{\frac{\text{(percent pasture)}}{\text{day}}}{.75} \times \underset{\text{pasture days}}{180} \times \frac{\text{Volume of Manure)}}{\text{day}} \times \underset{\text{N cleanouts}}{(1/3 + 1)}$$

Winter Spread Manure

$$\text{Runoff Load} = \text{Volume of Manure}\ \frac{(\text{kg})}{\text{year}} \times \underset{\text{winter spread}}{0.25} \times \underset{\text{delivered to stream}}{(0.1 \times 1.0^{9} \times 0.15)} \times \frac{\text{fecal coliform}}{\text{kg}} \times \underset{\text{stack decay}}{1 \times 10^{-1.5}} \times \underset{\substack{\text{field decay}\\ \text{(bacteria only)}}}{[illegible]} \times \underset{\substack{\text{volume of manure}\\ \text{overspread}}}{[illegible]}$$

Summer Spread Manure

$$\text{Runoff Load} = \text{Volume of Manure}\ \frac{(\text{kg})}{\text{year}} \times \underset{\text{summer spread}}{0.75} \times \underset{\text{delivered to stream}}{(0.1 \times 1.0^{9} \times 0.15)} \times \frac{\text{fecal coliform}}{\text{kg}} \times \underset{\text{stack decay}}{1 \times 10^{-2}} \times \underset{\substack{\text{field decay}\\ \text{(bacteria only)}}}{[illegible]} \times \underset{\substack{\text{volume of manure}\\ \text{overspread}}}{[illegible]}$$

Volume of Manure

$$= \frac{\text{Volume of manure}}{\text{day}} \underset{\text{animals}}{\times} N \underset{\text{year}}{\times} \underline{365\ \text{day}} \times 1005\ \text{kg/m}^3\ \text{manure} \qquad \text{(P.L.O.P. p.34)}$$

Volume of Manure Per Animal

$$\underset{\text{animals}}{N} \times \underset{\text{values by animal type}}{\text{OMAF}}$$

APPENDIX 4: Remedial Costs Used in Capital Cost Analysis

Rural Contaminant Source	Remedial Facilities			
	Maximum Cost		Minimum Cost	
Milkhouse wastes	$ 6,000	Storage tank and spreading	$ 3,000	Treatment trench
Livestock access	$16,000	Fence 2 sides and alternate water	$ 6,000	Fence 1 side and alternative water
Feedlot, barnyard runoff	$ 4,992	Covered concrete tank	$ 1,829	Earthen lagoon
Manure stack runoff	$32,750	Covered solid storage		
	$17,210	Covered concrete tank	$13,641	Earthen lagoon
Household septic wastes	$ 3,000	Septic tank and weeping bed	$ 3,000	Septic tank and weeping bed

Source: Kempenfelt Workshop, 1988

APPENDIX 5: Total Pulse and Continuous Bacteria Discharges to A.B.C.A. Sub-Watershed Drains and Delivered to Lake Huron

FIGURE 11 : AUSABLE RIVER WATERSHED

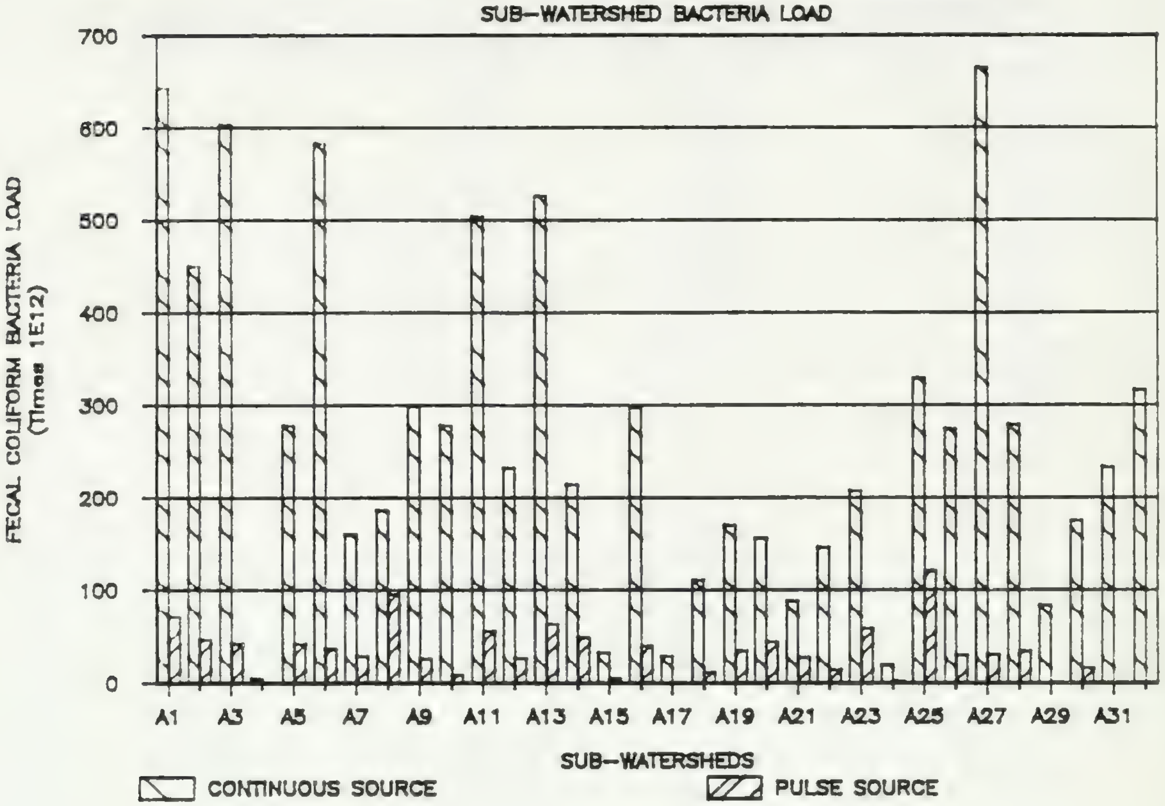


FIGURE 12 : AUSABLE RIVER WATERSHED

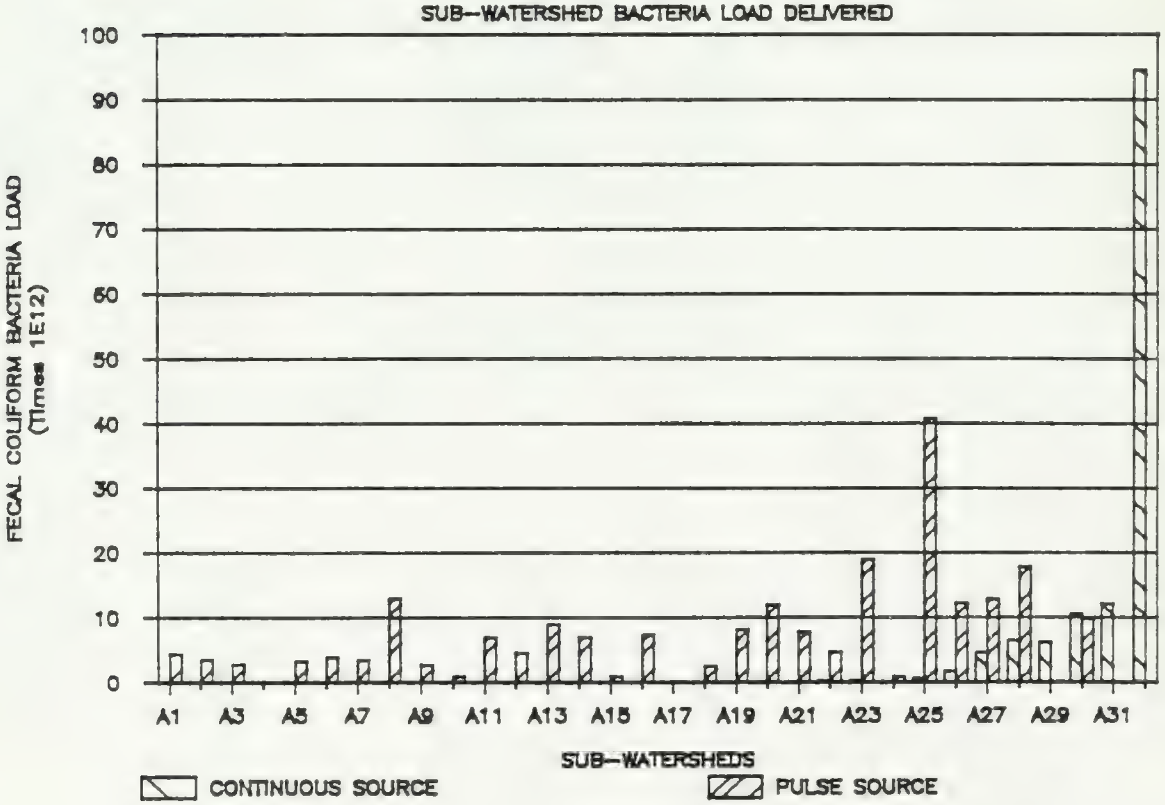


FIGURE 13 : BAYFIELD RIVER WATERSHED

SUB-WATERSHED BACTERIA LOAD

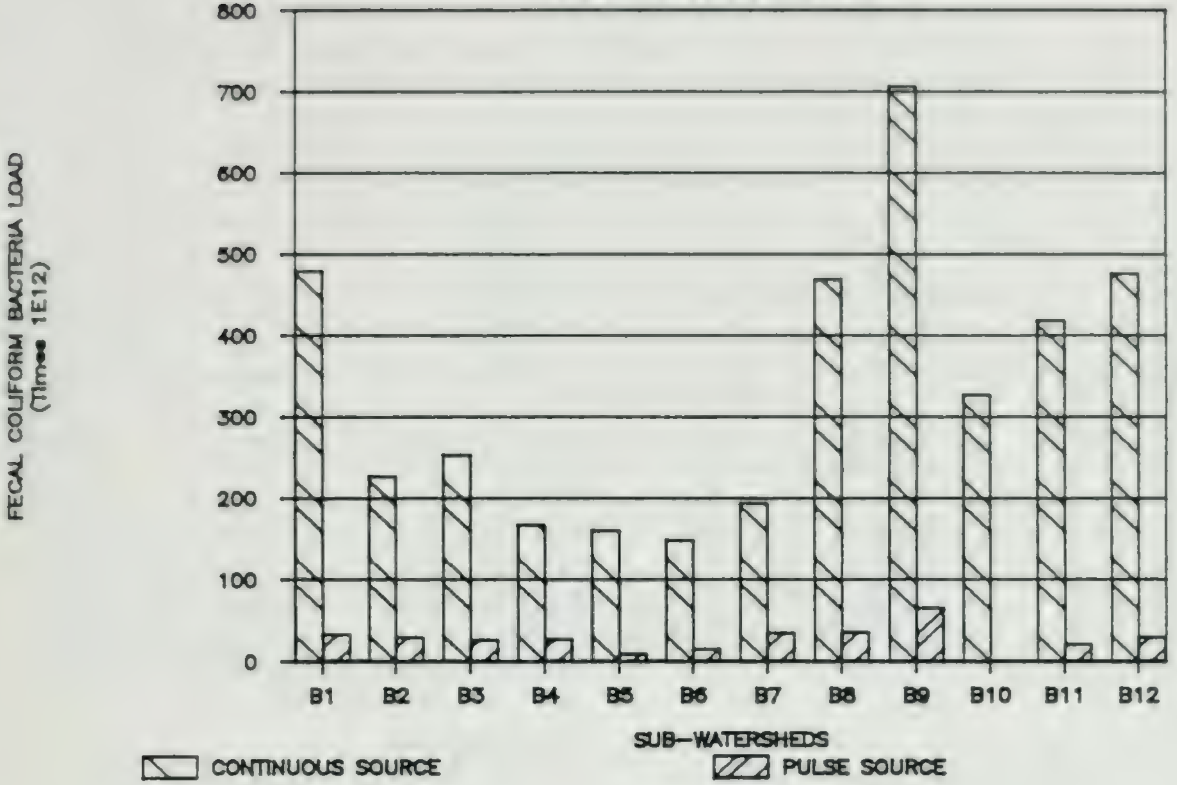


FIGURE 14 : BAYFIELD RIVER WATERSHED

SUB-WATERSHED BACTERIA LOAD DELIVERED

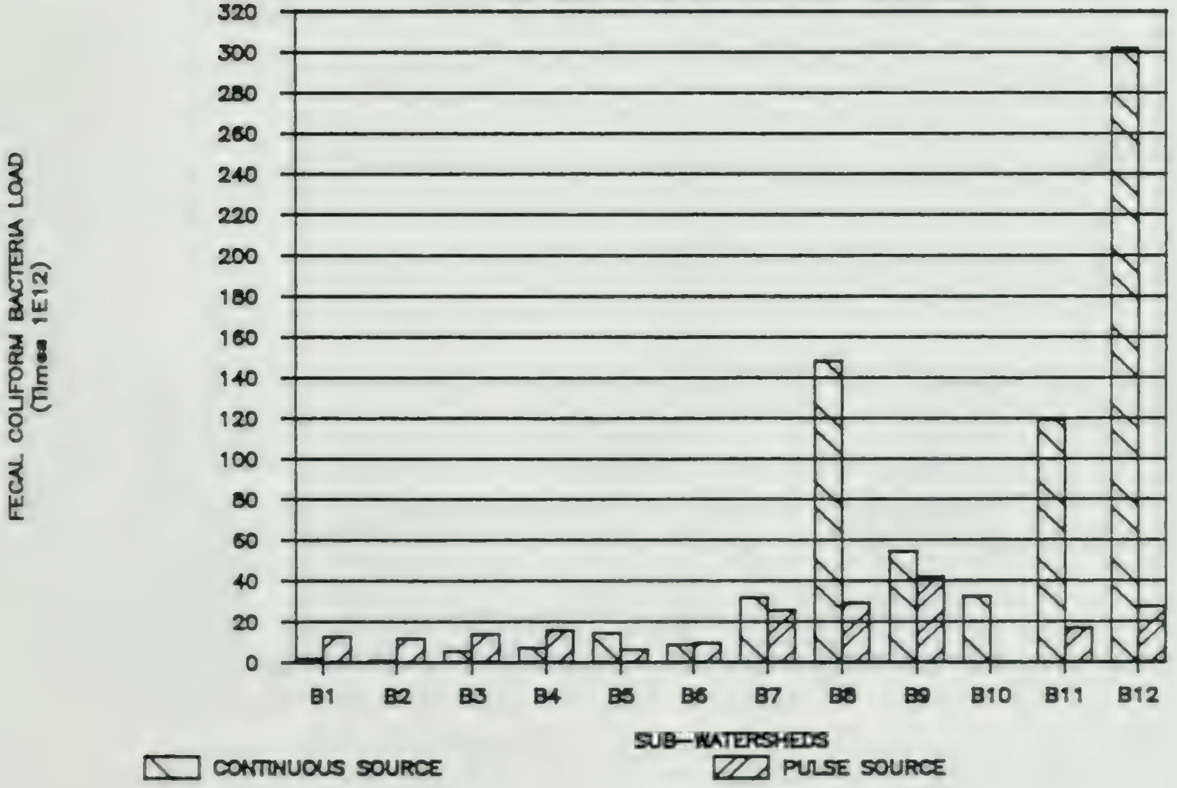


FIGURE 15 : PARKHILL CREEK WATERSHED

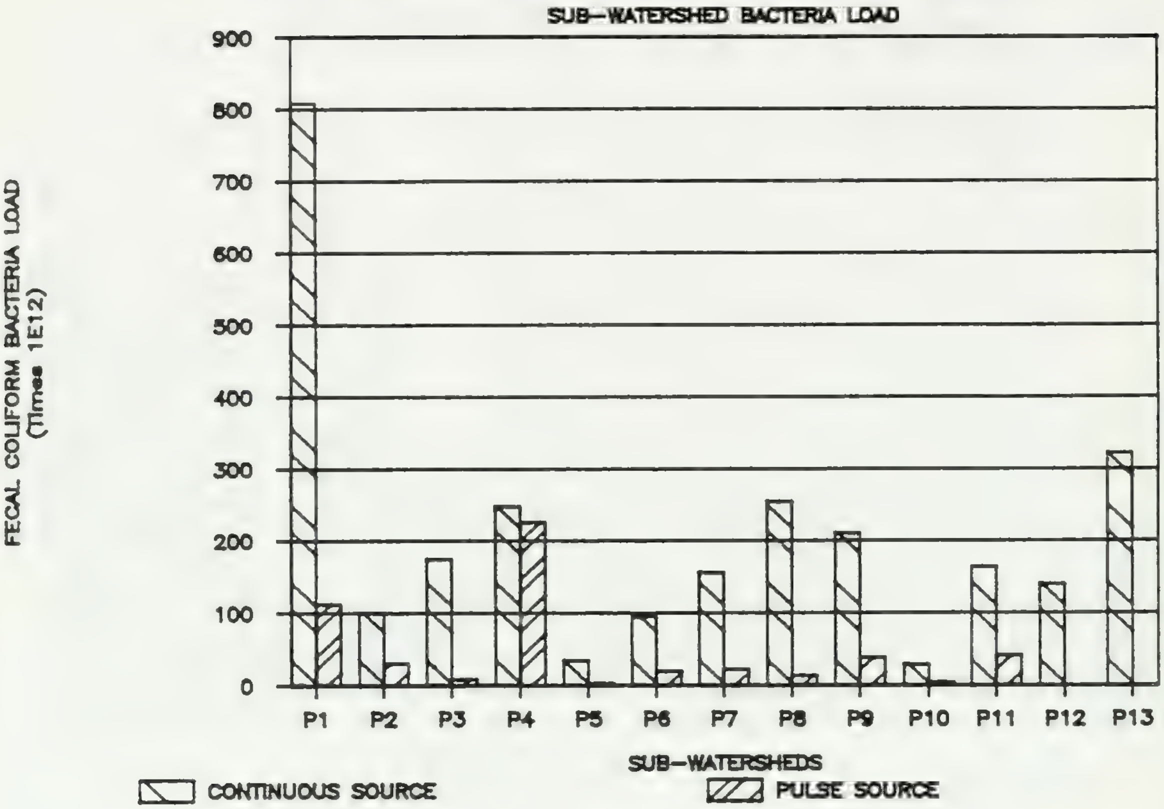


FIGURE 16 : PARKHILL CREEK WATERSHED

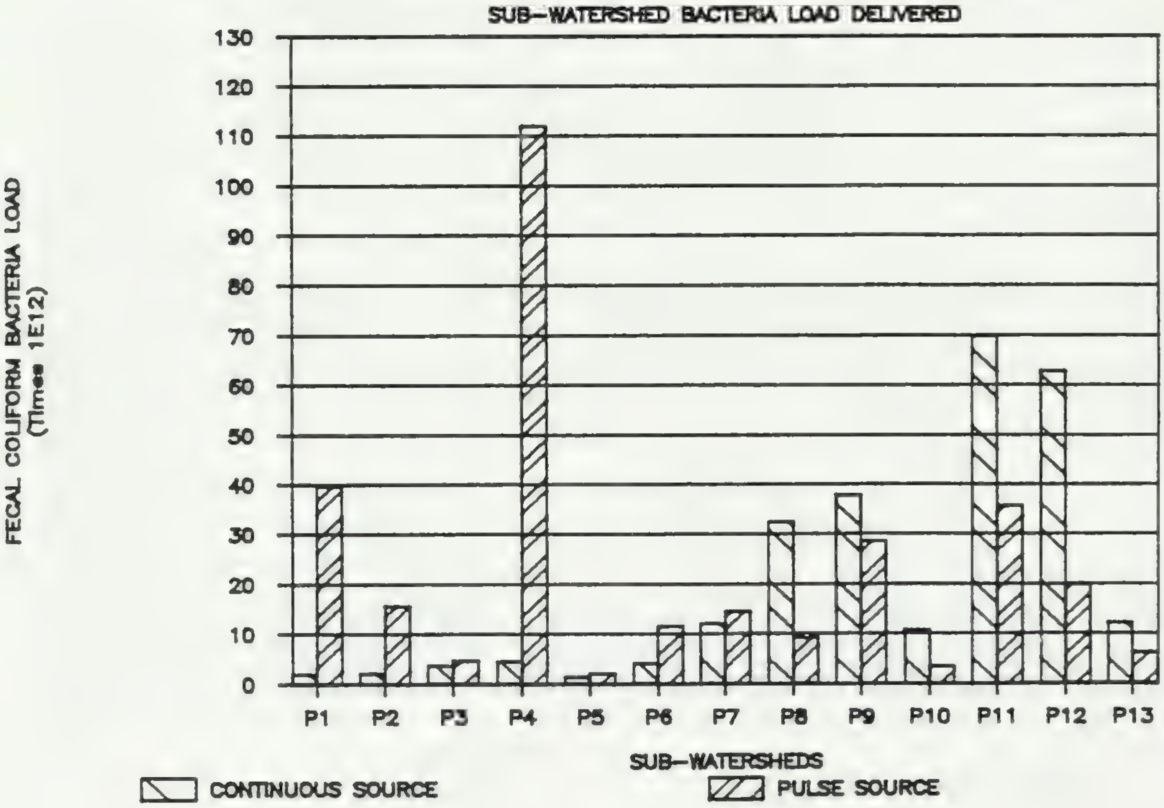


FIGURE 17 : MUD CREEK WATERSHED

SUB-WATERSHED BACTERIA LOAD

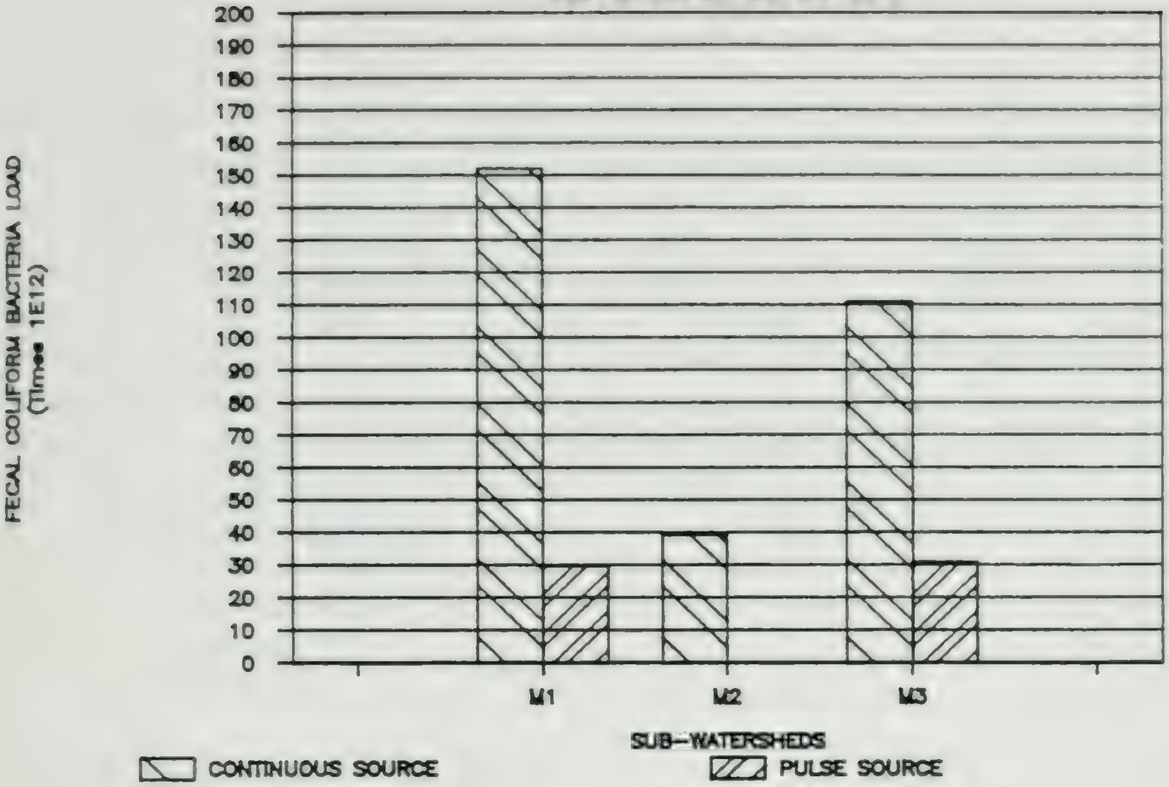


FIGURE 18 : MUD CREEK WATERSHED

SUB-WATERSHED BACTERIA LOAD DELIVERED

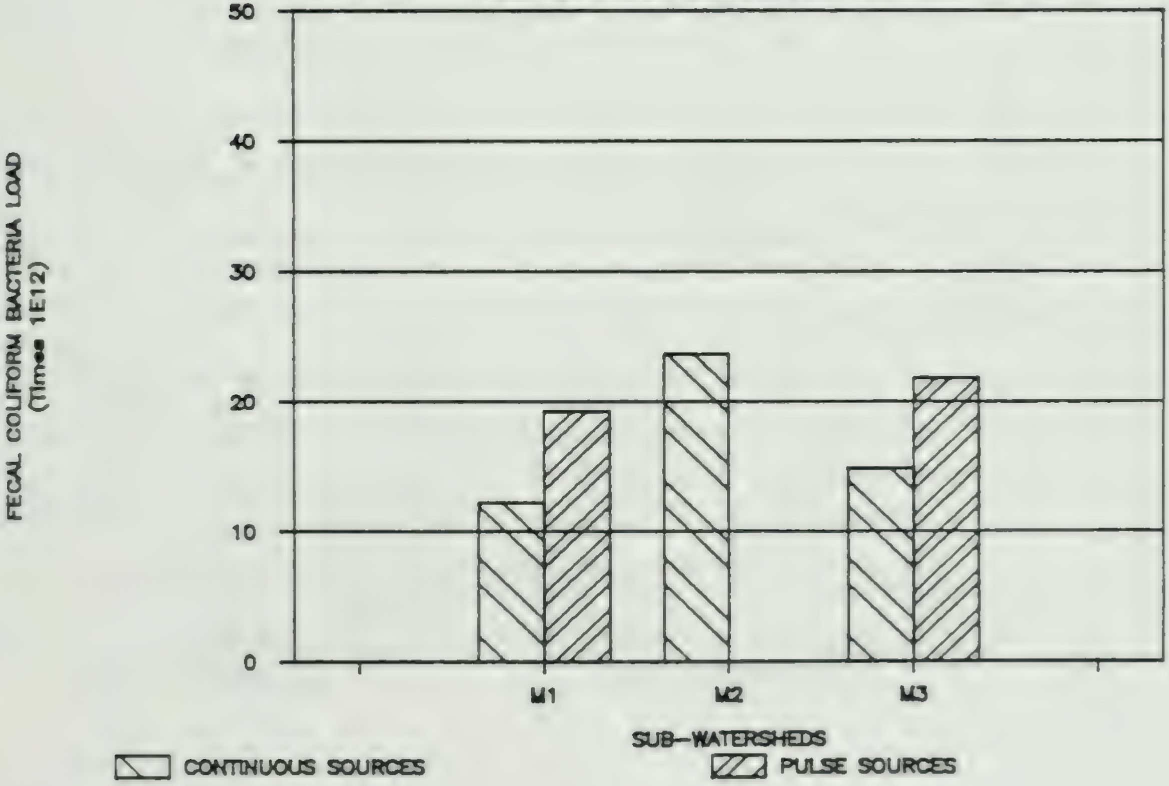


FIGURE 19 : GULLIES WATERSHEDS

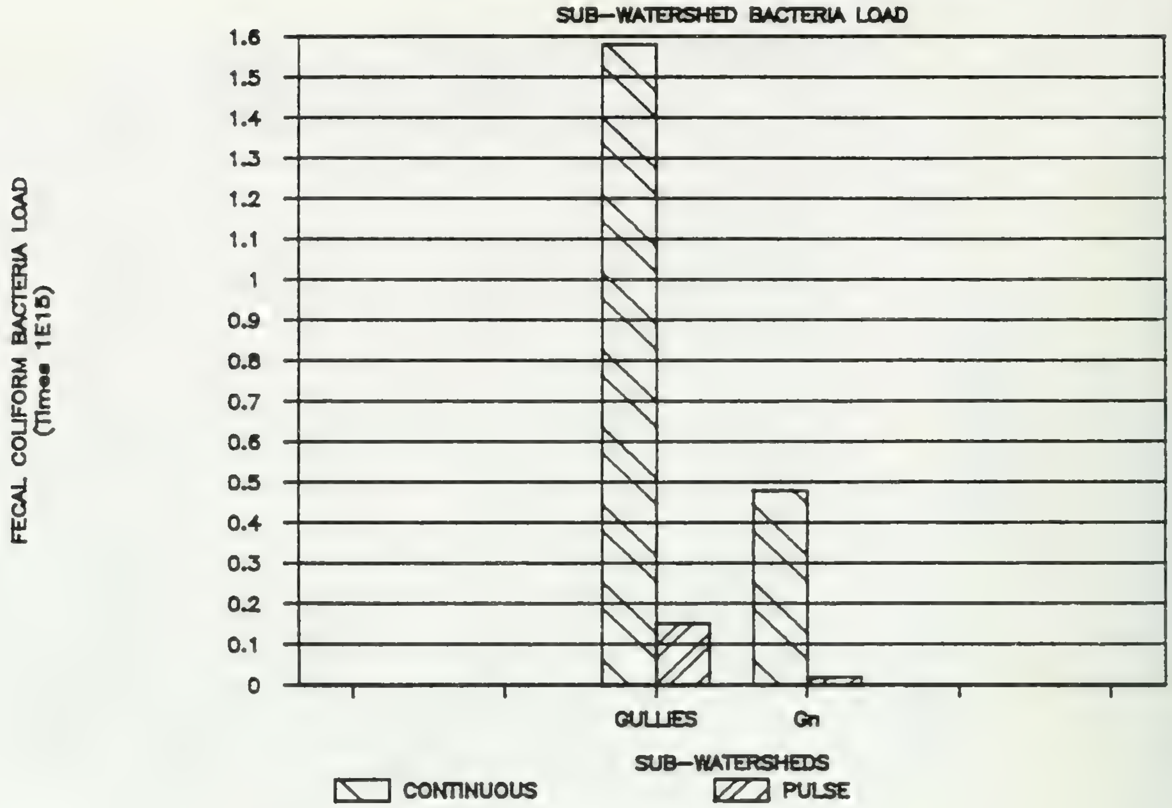
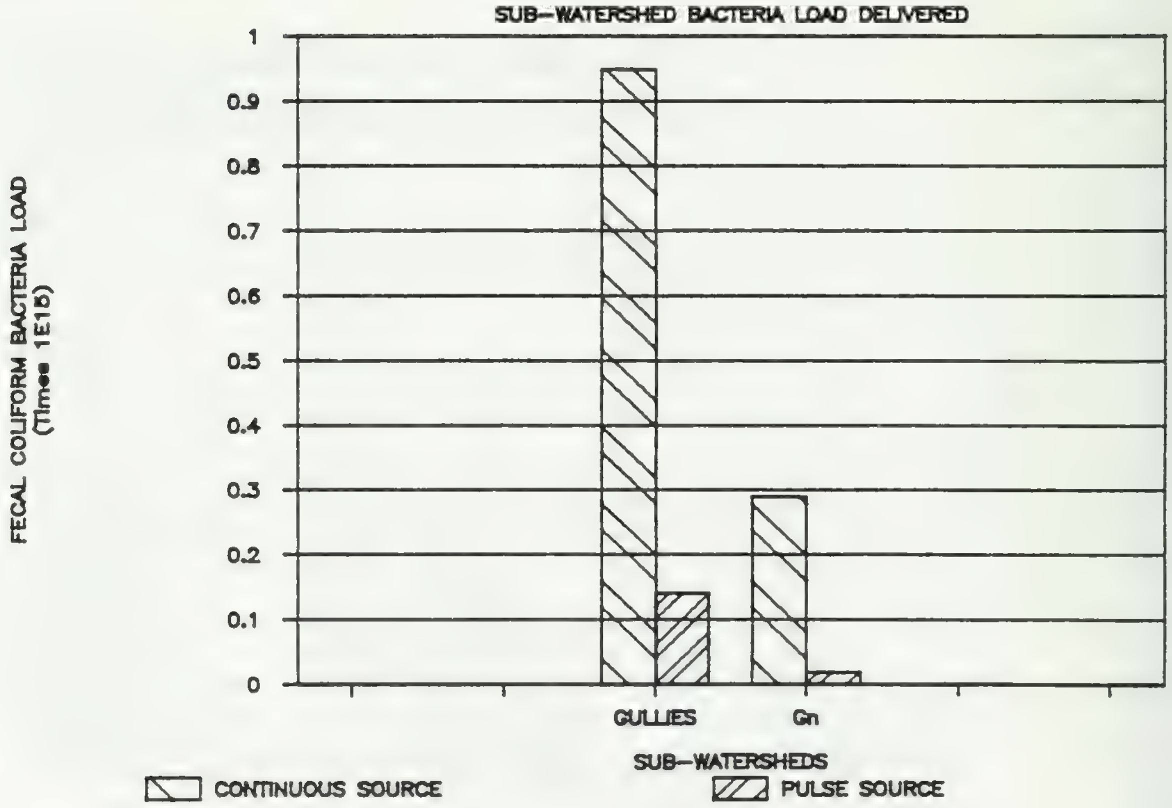


FIGURE 20 : GULLIES WATERSHEDS



persons in the summer months. Bayfield supports approximately 1,000 more summer residents (A.B.C.A., 1983).

The three villages support several marinas. Grand Bend has approximately 100 slips for transient boaters (Lingard, personal communication, 1989) Bayfield 600 (Graham, personal communication, 1989) and Port Franks in excess of 100 (A.B.C.A.) in addition to several private campgrounds in the immediate vicinity (P. Graham, personal communication, 1989). Bayfield's tourist economy is not as dependent upon the "beach crowd" as Grand Bend. In spite of higher lake levels reducing available public beach area in recent years, new tourist shops have been opened; 10 in 1988 and 2 to date (June) in 1989. While not strictly a retirement community, older people tend to set up these new shops and cater to more cultivated (and expensive) tastes (J. Dollery, personal communciation, 1989).

Summer recreation has considerable impacts on these villages. Each day a beach is closed, annual revenues in beach dependent businesses are reduced by 1.25 percent. Several days of beach closures will have dramatic economic impact. Sustained closures will indicate reduced drawing power of all natural attractions and seasonal tourist visitations will also drop, increasing a negative ripple or spin-off effect. Grand Bend itself is not a regional service centre (E.D.O., 1983). This weak diversification will leave Grand Bend and other tourism dependent villages in the A.B.C.A. jurisdiction vulnerable to downturns in the local tourist industry.

8.2 Non-Beach Impacts and Benefits

Implementation of the C.U.R.B. Plan will promote continued recreational use, development and investment in Lake Huron beach communities. This will provide tax bases for municipalities enabling implementation of contamination abatement strategies.

C.U.R.B. Plan strategies will change farm management practices, resulting in many off-beach benefits. Elimination of over-spreading will keep manure on the farm where the farmer's own crops will benefit from saved nutrients. Timely application will reduce soil compaction and protect soil structure, enhancing field crop performance.

Livestock operators will benefit from improved herd health and fewer veterinarian expenses. The etiology of sickness often overlooks water quality. Water can transmit serious diseases such as leptospirosis, salmonellosis, mastitis, foot and mouth disease, brucellosis, hog cholera, E. coli infections, tuberculosis, infectious hepatitis, gastro enteritis and typhoid fever. Approximately 60 to 85 percent of the daily nutrition of livestock is represented by water (W. Schilthuis 1985). Pork and poultry operations that have chlorinated water supplies often report significant increases in growth rate and production (Stanford, 1989, personal communication).

Livestock access has been documented as the source of a Salmonella munster outbreak in Wellington County. Between 1977 and 1980, the number of cases both human and animal doubled each year. S. munster causes abortion, diarrhea and death in cattle and just diarrhea in humans and other species. This epidemic was thought to be spread by oral ingestion of water contaminated by feces. This epidemic was brought under control in 1983 (Stanford, 1989, personal communication).

Stream banks will be protected and drain maintenance costs will be reduced by the elimination of livestock access. Erosion of stream banks and consequent sedimentation and eventual release of nutrients causing eutrophication of streams will be consequently avoided. Wildlife will not suffer due to degradation of their habitat and from barnyard diseases contracted through ground water.

Adoption of the C.U.R.B. Plan will be necessary to avoid more desperate future managment practices and more restrictive farm legislation. Continuous degradation of water resources will eventually require wide scale treatment of water resources and to farm animal waste before disposal. Success of C.U.R.B. Plan strategies will improve water resources in the A.B.C.A. watershed as well as preserving the natural drawing power of Lake Huron beaches.